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January, 1912. Chemical Series. Vol. II, No. 3.

Biological & Medical Serials

Memoirs of the Department of Agriculture in India

RECORDS OF DRAINAGE IN INDIA

BY

DR. J. WALTER LEATHER, PH.D., F.I.C., &c

Imperial Agricultural Chemist

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AGRICULTURAL RESEARCH INSTITUTE, PUSA

PUBLISHED FOR

THE IMPERIAL DEPARTMENT OF AGRICULTURE IN INDIA

BY

THACKER, SPINK & CO., CALCUTTA
W. THACKER & CO., 2, CREED LANE, LONDON

Price, Re. 1.

1911 CHEMICAL SERIES Vol. II, No. 2.

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PREFACE.

In addition to records obtained by the drain-gauges at Pusa, those of the Cawnpore gauges have been included in this memoir with the permission of the Director of Land Records and Agriculture, United Provinces, and I desire to take this opportunity of thanking him and the officers of that Department for the assistance they have given in respect of the work during the seven years for which we have information on the subject.

Pusa, August 1911. J. W. L.

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RECORDS OF DRAINAGE IN INDIA.

DRAIN-GAUGE RECORDS AT CAWNPORE, 1903-10, AND AT PUSA, 1906-10.

BY

DR. J. WALTER LEATHER, PH.D., F.I.C., &c.,

Imperial Agricultural Chemist.

PART I.

INTRODUCTORY.

FOUR gauges for the measurement of the amount of water which percolates through agricultural land, were constructed at the Cawnpore Agricultural Experiment Station in 1903 and four similar gauges at the Agricultural Research Institute, Pusa, in 1906, and their construction has been fully described.(1)

It will be sufficient for the purposes of this communication to state that all these gauges are similar to those at Rothamsted, and consist of blocks of ordinary agricultural land measuring 1/1000 acre superficially, which were isolated and walled in, and have "false bottoms" inserted beneath them; at each station two of these gauges are 3ft. deep and two are 6ft. deep. It is important to note that these blocks of earth were in no way disturbed, not even cracked, during the process of inserting the false bottoms and building the walls. Below the false bottom, each gauge has apparatus for collecting and measuring the drainage water which comes through.

(1) Ann. Rep. Cawnpore Farm, 1905-6, p. 23 and Memoir of the Dept. Agri., Chem. Series, Vol. I, No. 5.

In addition, the gauges at Pusa have overflow pipes connected to subsidiary tanks to take off "*surface*" *drainage*, which is thus measured separately.

We have now seven years' records from the Cawnpore gauges and four from those at Pusa. Such periods are admittedly very short, for it is to be recollected that no two gauges behave exactly alike, and that seasonal differences affect both the quantity and quality of the drainage water. Nevertheless some of the information which has been collected is of considerable interest and forms an aid to a better appreciation of what happens during wet weather in India, not only in regard to the disposal of the rain-water, but also as to the formation and disposal of the nitrate.

In addition to information obtained with these gauges, a record of the nitrate present in some fallow soil near to the gauges has been kept, and these data are of assistance in drawing certain conclusions.

Methods of Analysis employed.

Ammonia.—This has been determined as usual by Nessler's method.

Nitrate in drainage waters.—The nitrate has been determined by Warington's modification of Schloesing's method in the drainage water of Cawnpore in samples prepared fortnightly from aliquot portions of the daily drainage. That in the Pusa drainage has been determined (i) *daily* by the phenol-disulphonate method as described by Richardson and Hollings,(2) and (ii) in weekly or fortnightly samples, made from aliquot portions of the daily drainage, by Schloesing's method. The phenol-disulphonate method has been found to be more reliable than was anticipated, the error being considerably less than 1/10. The following data of

(2) Jour. Soc. Chem. Ind., XXII, 1903, p. 616.

lbs. of N per acre illustrate the differences found by the two methods :—

—	Gauge I.	Gauge II.	Gauge III.	Gauge IV.
	lbs. Nitric Nitrogen per acre.			
1909.				
By Schloesing's method	261·5	51·1	209·6	53·3
By Phenol-disulphonate*	275·5	53·9	215·6	54·9
1910.				
By Schloesing's method	17·1	..	36·6	·4
By Phenol-disulphonate*	18·6	..	39·0	·3

* These figures are in each case the sum of the numerous individual determinations.

The advantage of maintaining a daily record is that variations of concentration can be brought into comparison with the drainage.

Nitrate in the soil.—At the time of constructing the Cawnpore Gauges no estimate was made of the amount of nitrate initially present in the soil; but when those at Pusa were about to be constructed it was decided to ascertain this quantity with as much precision as possible. Before however attempting to carry this into effect, experiments were made to ascertain the best means of extracting nitrate from the soil.

Warington(3) considered the best plan to consist in (i) drying the soil at a temperature of about 38°C., and (ii) extracting the nitrate by percolating water through the soil under pressure. In this manner he obtained the nitrate from the soil in comparatively little water. In so far as the latter process is concerned I have found it usually works extremely well. But as regards the preliminary treatment of the soil my experience hardly coincides with his. Not having a dark room of the required temperature (38°C.), his method has not been really tried. But if a soil be exposed in a layer about one-half inch thick to the sun in India and repeatedly stirred, it becomes air-dry in about 4 hours, and under these circumstances an increased amount of nitrate usually forms. In order to test this point the following experiments were made. In each case about 10 kilos of soil from an arable field was well mixed. Of this about 4,000 grms. was spread out in the sun and dried as quickly as pos-

(3) Jour. Chem. Soc., Trans. 1882, p. 352.

sible, the nitrate being subsequently extracted by Warington's method. Also about 4,000 grms. of the fresh and undried soil was treated with a known quantity of water, a little gypsum added to coagulate the clay, shaken for a few minutes and then filtered on a Buchner funnel by the aid of a pump. The filtrate was measured, from which its proportion to the whole quantity of liquid in the soil was ascertained. The filtrate was then sterilised by being heated to boiling, evaporated to small volume and the nitrate was then determined by Schloesing's method. At the same time the moisture in the fresh soil was determined in order that the total water used could be ascertained. For example, 5,666 grms. fresh earth containing 18% moisture (= 1,020 c.c.) was treated with 4,800 c.c. water; total water equals 5,820 c.c. Filtrate obtained = 3,900 c.c. NO = 1·6 c.c. Hence N = ·00129 grms. = ·277 part per million.

As illustrating the effect of air-drying in the manner mentioned, the following figures may be quoted:—

Specimen.	Grms. Nitric Nitrogen per 4,000 Grms. Soil.		
	Soil air-dried.	Soil treated immediately with water and filtered.	
I	·0184	·0043	·0042
II	·0062	·0035	·0037
III	·0052	·0048	·0050

It will be readily conceded that, if the nitrate, or a known proportion of it, can be extracted in a short time, such as half an hour, and the solution sterilised, any such method is on the whole preferable to one which includes the preliminary drying of the soil.

In more recent work about 100 grms. of fresh soil has been added to 400 c.c. water, about 1 grm. gypsum added, the mixture filtered (an ordinary filter without pump suffices) and about 200 c.c. of the filtrate is sterilised by heat; the nitrate is then determined in a part of the extract by the Phenol-disulphonate method. By this means not more than 20 minutes elapses between taking the sample and the sterilisation of the extract, which is a most expeditious method, and one which may be conducted in a tent in

the field. The water present in the fresh soil is naturally also determined and the results expressed per unit weight of dry soil or per unit volume of the soil.

The Soils.—A brief description of the two soils may be of interest.

The Cawnpore Soil.—Cawnpore is situated in the Gangetic Alluvium. The whole of this is entirely free from stones and gravel and consists purely of very fine soil material, none of it being larger than 1 mm. diameter, excepting the concretionary limestone (vernacular *kankar*) which occurs in beds of a thickness varying from a few inches to several feet. The total depth of this alluvium is unknown, borings to as much as 1,000 feet having failed to locate original rock. The soil of these gauges has not been specially examined chemically. It is uniform in so far as the eye can tell, that is, no distinct beds of sand or clay are present. A stratum 4ft. to 1ft. in thickness containing some *kankar* nodules lies obliquely through Gauges Nos. I and II. It is thickest in gauge No. II extending from 3′ 6″ down to the base of the gauge. In gauge No. I there is only a little between 5′ 0″ and 6′ 0″. The two 3ft. gauges contain practically no *kankar*. This *kankar* does not seem to make the soil much less pervious to water.

The permeability of the soil to water is indicated as follows and shows that it is rather more "open" than the Pusa soil.*

Depth.	Cm. per hour.
0′ 0″ — 0′ 6″	·52
1′ 0″ — 1′ 6″	1·00
2′ 0″ — 2′ 6″	·69
3′ 0″ — 3′ 6″	·61
4′ 0″ — 4′ 6″	·88
5′ 0″ — 5′ 6″	1·00

The land at the site of the gauges had been used, prior to their construction in 1902, for about 20 years for various field experiments. During that period it had been manured ten times, latterly with farm manure and poudrette. It had latterly borne *kharif* (monsoon) crops such as sorghums, rather than *rabi* (cold

* It is intended to publish an account of the method employed for this test very shortly.

weather) crops, and was in fairly high condition. The last crop grown prior to the construction of the gauges was cajanus indicus with sorghum in 1901, when 100 maunds (about 4 tons) of farm manure was used per acre.

The Pusa Soil.—This estate had been in a great measure uncultivated for years prior to 1904 when it was taken over by the Agricultural Department. The land at the site of the gauges was cultivated for one year and then put down to grass. This land, like that at Cawnpore, forms part of the great alluvium and consists purely of fine material of unknown depth. It differs, however, from the Cawnpore soil in that it includes about 40% of fine chalk. The first two feet are "loamy," the next two are much more sandy, whilst the 5th and 6th feet are a comparatively stiff clay. It contains no *kankar*. At the time of making the gauges this soil was sampled to a depth of six feet, and the following determinations were made :—

Feet deep.	Organic Nitrogen.	Organic Carbon.	$CaCO_3$	Total P_2O_5	Available P_2O_5	Available K_2O.	sp. gr.
1st ..	·0562	·420	35·4	·094	·0002	·0046	2·66
2nd ..	·0456	·322	34·8	·056	·0003	·0054	..
3rd ..	·0244	·099	40·1	·039	·0002	·0015	..
4th ..	·0205	·091	42·3	·064	·0001	·0023	2·72
5th ..	·0200	·115	43·5	·058	·0002	·0070	2·73
6th ..	·0180	·136	44·6	·057	·0002	·0078	..

Rate of percolation of water.

Depth.	Cm. per hour.
1′ 9″ — 2′ 0″	·168
2′ 9″ — 3′ 0″	·870
3′ 9″ — 4′ 0″	·312
4′ 9″ — 5′ 0″	·072

The amount of nitrate present was likewise determined at five different places in the land adjoining the site of the gauges, when the following amounts were found to a depth of 6ft.

	Parts N per million soil.
1st boring	no nitrate.
2nd boring	Do.
3rd boring	·277
4th boring	·208
5th boring	·140

These amounts are equivalent to less than ·003 lbs. Nitric nitrogen per 6ft. gauge. It was thus well established that the soil of these gauges contained practically no nitrate initially.

Character of the Seasons.—Before entering upon a discussion of the data, a description of the general character of the seasons will be of interest to those who are unacquainted with India.

In the accompanying statement No. I the average rainfall of Cawnpore is set out; for Pusa we have not sufficient records to provide a dependable average, and accordingly the rainfall of the four last years is given in detail. The data for the years of drainage are also illustrated by charts I and II.

Statement No. I.

Rainfall data at Cawnpore and at Pusa.

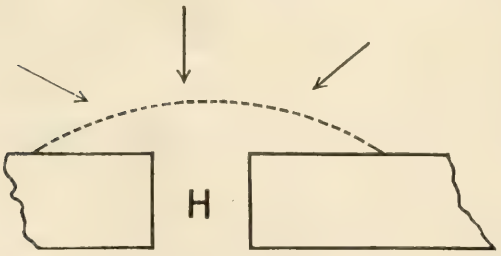
Period.	Cawnpore.			Pusa.			
	Average of 8 years 1891-9. Inches.	Average of 8 years 1900-7. Inches.	Average of 19 years 1891-1910. Inches.	1906-7. Inches.	1907-8. Inches.	1908-9. Inches.	1909-10 Inches.
November ..	·48	·05	·22	*Nil*	*Nil*	*Nil*	*Nil*
December ..	·27	.36	·36	*Nil*	*Nil*	·04	·12
January ..	·64	.37	·47	*Nil*	·03	·11	·01
February ..	·50	·74	·54	1·22	2·27	·23	·02
March ..	·05	·25	·13	1·77	·15	*Nil*	·07
April ..	*Nil*	·08	·20	·89	*Nil*	3·47	·14
May ..	·33	·22	·30	·30	·92	1·34	·40
June ..	3·57	2·55	2·90	6·88	1·48	28·96	7·46
July ..	9·60	9·32	10·04	7·64	7·24	9·08	9·34
August ..	13·61	9·09	11·09	6·14	3·85	24·11	6·88
September ..	6·23	7·78	6·33	14·80	4·97	3·37	3·70
October ..	1·73	1·30	1·28	*Nil.*	·58	2·90	4·16
Total ..	37·01	32·11	33·86	39·64	21·49	73·61	32·30

It will be seen that whilst the average rainfall at Cawnpore is about 34″, that at Pusa amounts to about 40″ so far as we can tell at present. From the end of October until the end of the following May the rainfall is restricted to showers which at the most merely damp the first foot of soil; consequently drainage does not occur at the bottom of these gauges until the heavy rain of the monsoon sets in. During the following four months Cawnpore may

expect nearly thirty inches, and Pusa has apparently over thirty inches. Consequently practically all the drainage of the year is met with during this period. Some of this rain falls in very heavy showers, nearly every year experiences one or more falls of four or five inches in twenty-four hours, whilst seven and eight inches are not uncommon. At such times some of the rain-water runs off the land into the nearest channel. How much actually does so must necessarily depend on a variety of circumstances. The matter is more fully discussed on pp. 85—88.

Cause of muddy drainage water.—Before discussing the data, reference may suitably be made to the earth which not infrequently comes out of these gauges with the water.

In the accompanying woodcut is shown a section through a part of the iron plate on which the soil rests; the section passes through one of the holes, H in the plate. When drainage is in progress the course of the water is vertical through the greater part of the soil, but as it approaches the false bottom, its direction is deflected towards the nearest hole in the plate. The result is that there is a tendency to an increased velocity in its neighbourhood, and since in times of very wet weather the soil of the gauge is carrying off its maximum amount of water, the velocity near the hole becomes so great that soil will be carried away and a cavity formed above the hole, as indicated by the dotted line. Such a cavity having formed, the water will not remove any more earth, and the drainage will become clear.



Such is the general statement of the case. It follows that the size of the cavity and its stability will depend on (i) the maximum rate of flow, and (ii) on the nature of the soil. For any particular velocity of flow a smaller cavity will form in a sandy than in a clayey soil. A cavity having thus formed, the question then follows as to

CHART I SHOWING CAWNPORE RAINFALL.

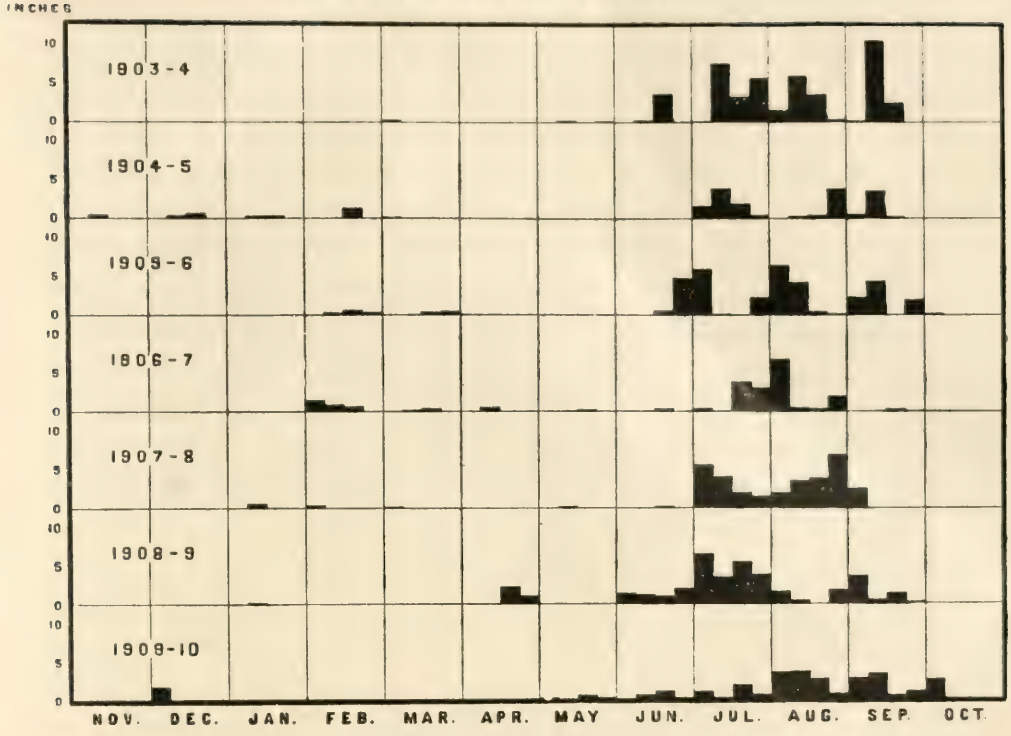
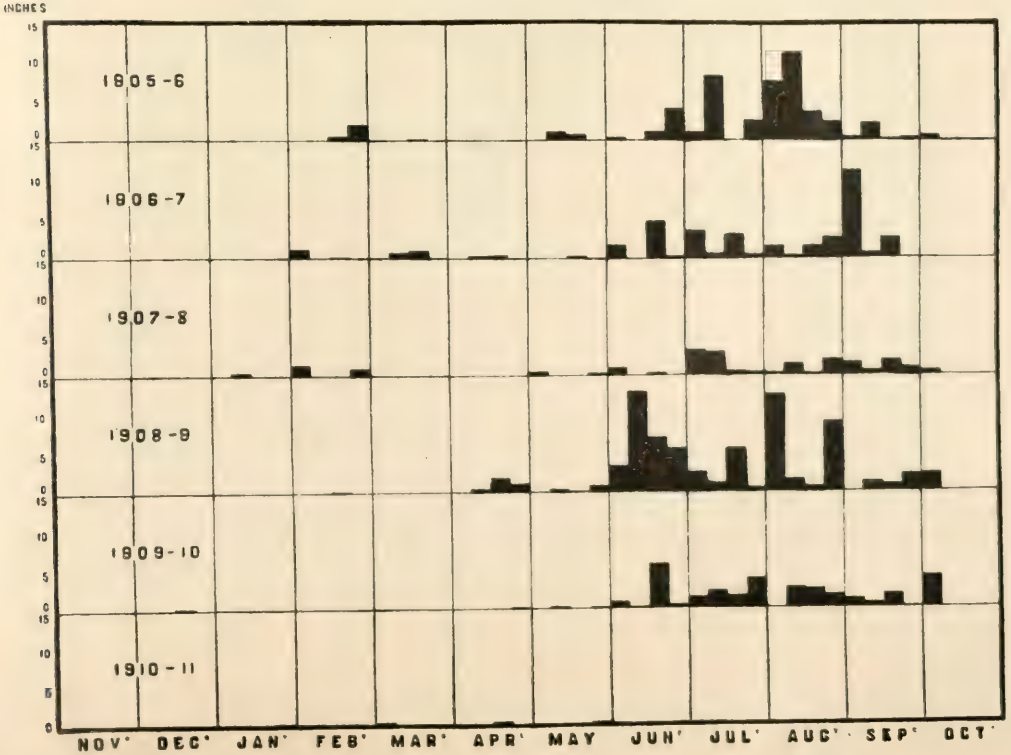


CHART II SHOWING PUSA RAINFALL.



its stability. The cavities *in the clay* are probably fairly stable, and as a result the drainage from gauges I and II is usually clear or only slightly muddy. But the corresponding cavities in the *sandy soil* of Nos. III and IV gauges may be expected to be unstable. In fact, when the gauges were about to be made I considered what the risk would be on this account of these gauges breaking down altogether. It was desired to have them of the same dimensions as the Cawnpore gauges, and for this reason they were constructed 3ft. deep, but there was certainly a doubt as to whether they would break down. Experience has shown, however, that they are quite stable. A pound or so of earth may pass away in a season, but this is such a small fraction of the whole that they are certain to yield many years' records. Up to the present no perceptible subsidence has taken place at the surface.

PART II.

Drainage and Evaporation.

Drainage from bare fallow land.—As already mentioned we have data of the amount of water which has passed through these gauges, of the water which runs off the land (at Pusa), and *by difference* the amount of evaporation. The details of these quantities are set out in Statements Nos. IX to XIV at the end of this memoir. The condensed annual data for the two stations are set out in Statements Nos. II and III. For each station the drainage year has been taken from November 1st to October 31st. The reason for this is that by November 1st all drainage of the monsoon will have ceased in any year, subsequently to which there is no drainage until the following monsoon.

In considering the information that has been obtained we may conveniently compare it with the corresponding Rothamsted records. At the English station the gauges have shown that the amount of percolation varies directly with the rainfall, whilst the amount which evaporates is approximately constant and varies only slightly with the rainfall, being rather greater in a *wet* year. Thus at Rothamsted with 41″ of rainfall, the drainage was 25″ and the evaporation 16″; with a rainfall of 19·5″, the drainage was 6″ and the evaporation 13″. The amount of water which evaporates per unit of time from a soil depends largely on whether the water has to travel a long or a short distance to the surface; hence during wet weather, when the surface soil is moist, evaporation will necessarily be high. Of course this is only one of the determining factors; the character of the soil and the atmospheric temperature and humidity being others; but for any one place, that is for the same soil, the amount which evaporates will be greater in wet than in dry weather.

Statement No. II.

Amount of annual rainfall, drainage and evaporation at Cawnpore.

Year.	Rainfall. Inches.	Drainage. Inches.	Overflow Inches.	Evaporation and transpiration, obtained by difference, Inches.
Gauge No. I, 6ft. deep.				
Novr. 1st 1903 to Octr. 31st 1904 ..	46·51	21·22	4·0	21·29
,, 1904 ,, 1905 ..	20·61	3·14	..	17·47
,, 1905 ,, 1906 ..	36·49	19·13	..	17·44
,, 1906 ,, 1907 ..	20·89	3·64	..	17·25
,, 1907 ,, 1908 ..	32·66	14·56	..	18·10
,, 1908 ,, 1909 ..	37·53	13·16*	..	24·37
,, 1909 ,, 1910 ..	28·35	4·53*	..	23·82
Gauge No. II, 6ft. deep.				
Novr. 1st 1903 to Octr. 31st 1904 ..	..	..	..	..
,, 1904 ,, 1905 ..	..	..	..	..
,, 1905 ,, 1906 ..	36·49	16·84	..	19·65
,, 1906 ,, 1907 ..	20·89	4·83	..	16·06
,, 1907 ,, 1908 ..	32·66	14·41	..	18·25
,, 1908 ,, 1909 ..	37·53	16·47	..	21·06
,, 1909 ,, 1910 ..	28·35	7·37	..	20·98
Gauge No. III, 3ft. deep.				
Novr. 1st 1903 to Octr. 31st 1904 ..	46·51	22·48	3·0	21·03
,, 1904 ,, 1905 ..	20·61	2·92	..	17·79
,, 1905 ,, 1906 ..	36·49	18·24	..	18·25
,, 1906 ,, 1907 ..	20·89	5·92	..	14·97
,, 1907 ,, 1908 ..	32·66	15·61	..	17·05
,, 1908 ,, 1909 ..	37·53	16·47	..	21·06
,, 1909 ,, 1910 ..	28·35	8·09	..	20·26
Gauge No. IV, 3ft. deep.				
Novr. 1st 1903 to Octr. 31st 1904 ..	..	..	..	..
,, 1904 ,, 1905 ..	20·61	3·57	..	17·04
,, 1905 ,, 1906 ..	36·49	19·94	..	16·55
,, 1906 ,, 1907 ..	20·89	6·80	..	14·09
,, 1907 ,, 1908 ..	32·66	16·18	..	16·48
,, 1908 ,, 1909 ..	37·53	16·15*	..	21·38
,, 1909 ,, 1910 ..	28·35	6·23*	..	22·12

* Juar was grown.

Owing to the fact that the record from two of the gauges did not commence at first, as also because crops have been grown on

two of them during the last two years, a comparison of the above data is not quite simple. For this reason the following *averages* may be of assistance :—

Period.	Rain-fall.	Gauge No. I.		Gauge No. II.		Gauge No. III.		Gauge No. IV.	
		Drain-age.	Evapo-ration.	Drain-age.	Evapo-ration.	Drain-age.	Evapo-ration.	Drain-age.	Evapo-ration.
5 years 1904-8	31·4	12·3	19·1	..	..	13·0	18·4	..	..
3 years 1906-8	30·0	12·4	17·6	12·0	18·0	13·3	16·7	14·6	15·4
		cropped						cropped	
2 years 1909-10	32·9	8·8	24·1	11·9	21·0	12·3	20·6	11·2	21·7

Statement No. III.

Amount of Annual Rainfall, Drainage and Evaporation at Pusa.

Year.	Rainfall. Inches.	Drainage. Inches.	Overflow. Inches.	Evaporation and trans-piration obtained by difference. Inches.
Gauge No. I, 6ft. deep (Fallow).				
Novr. 1st 1906 to Octr. 31st 1907 ..	39·72	6·96	4·02	28·74
,, 1907 ,, 1908 ..	21·92	*Nil.*	*Nil.*	30·46*
,, 1908 ,, 1909 ..	75·70	28·39	8·32	30·46*
,, 1909 ,, 1910 ..	32·30	6·41	*Nil*	25·89
Mean ..	42·41	10·44	3·08	28·89
Gauge No. II, 6ft. deep (Cropped).				
Novr. 1st 1906 to Octr. 31st 1907 ..	39·72	4·64	·85	34·23
,, 1907 ,, 1908 ..	21·92	*Nil.*	*Nil.*	31·95*
,, 1908 ,, 1909 ..	75·70	32·48	1·24	31·95*
,, 1909 ,, 1910 ..	32·30	*Nil.*	*Nil.*	..
Mean ..	42·41	9·28	·52	..

* Since there was no drainage in 1908, these amounts of *mean* evaporation for two years have been obtained by deducting drainage plus overflow of 1909 from the rainfall of the two years, and dividing the difference by 2.

Year.	Rainfall. Inches.	Drainage. Inches.	Overflow. Inches.	Evaporation and transpiration obtained by difference. Inches.
Gauge No. III, 3ft. deep (Fallow).				
Novr. 1st 1906 to Octr. 31st 1907 ..	39·72	8·77	·56	30·39
,, 1907 ,, 1908 ..	21·92	*Nil.*	*Nil*	28·75*
,, 1908 ,, 1909 ..	75·70	34·76	5·35	28·75*
,, 1909 ,, 1910 ..	32·30	6·49	*Nil*	25·81
Mean ..	42·41	12·50	1·48	28·42
Gauge No. IV, 3ft. deep (Cropped).				
Novr. 1st 1906 to Octr. 31st 1907 ..	39·72	9·08	1·20	29·44
,, 1907 ,, 1908 ..	21·92	*Nil.*	*Nil*	26·92*
,, 1908 ,, 1909 ..	75·70	39·57	4·21	26·92*
,, 1909 ,, 1910 ..	32·30	1·38	*Nil.*	30·92
Mean ..	42·41	12·51	1·35	28·55

Turning now to the Cawnpore data, it is to be observed that all four gauges were maintained fallow, like those at Rothamsted, until 1909, when Juar (Sorghum vulgare) was grown on No. I (6ft. deep) and on No. IV (3ft. deep) during the monsoon. Nos. II and IV yielded no data at first. No. II gauge was indeed, exposed to unusual drying affects, because the brickwork on one side had to be removed in 1905 for the purpose of inserting the collecting and measuring apparatus, and its upper face was at the same time protected from all rain. This fact no doubt accounts for the deficient drainage in 1906 from this gauge. The measuring apparatus of No. IV was at first defective, which explains why its record only commenced in 1905.

These data also include items 4″ and 3″ respectively, of overflow in the first year. The circumstances were as follows. On September 9th 8·40″, on September 10th 2·05″, on September 11th ·17″

* Since there was no drainage in 1908, these amounts of *mean* evaporation for two years have been obtained by deducting drainage plus overflow of 1909 from the rainfall of the two years, and dividing the difference by 2.

of rain fell, after which no rain fell for some days. Owing to the fact that these gauges are not provided with means for carrying off excessive rain water, some of this water overflowed the coping stones and was lost. The drainage of these and the succeeding three days from No. I gauge was 5·27″ before the next fall, and from No. III gauge, 6·47″. Judging from the general behaviour of these gauges, during stormy weather, there would have percolated about 9 or 9½″ had none been lost, and it has therefore been concluded that about 4″ overflowed from No. I and about 3″ from No. III gauge. The amount is obviously only an approximation, but is useful in forming an estimate of the annual evaporation.

Of the *Pusa* gauges Nos. I and III have been maintained fallow throughout, whilst Nos. II and IV have carried crops. We are therefore only concerned with the two former at present.

A comparison of the amounts of drainage from the several gauges shows that the differences have been, at times, somewhat greater than has been found to be the case at Rothamsted. Such differences in the amount of drainage between one gauge and another at Rothamsted have amounted to 1·5″ and 2″. At Cawnpore in 1906 the smallest quantity of drainage was 3·6″ from No. I gauge and the largest 6·8″ from No. IV, but in all other cases these differences have been less than 2″. At Pusa the differences between fallow gauges were greater in 1909, when No. I yielded 28·4″, No. III 34·7″, but a great part of this difference was due to a greater amount of overflow from No. I during the early part of the monsoon. In other years the differences have been less than 2″ from these fallow gauges.

An examination of Statements Nos. II and III shows at once how much the percolation varies with the rainfall. At Cawnpore as much as 20″ has percolated in a wet year; as little as 3″ in a dry one. The amount which evaporates during the 12 months is almost constant, or at least varies in only a subordinate degree and is generally highest in a wet year.

Similarly at Pusa with 40″ of rain there was about 7″ or 8″ of percolation *from fallow soil* (gauges Nos. I and III); no percolation in 1908 when the rainfall aggregated only 22″; and about 30″ of

percolation in 1909 when the rainfall aggregated 75″. The evaporation figure is on the other hand very fairly constant. It seems certain, then, that these two facts are now well established and are applicable to all soils.

At the same time there is a very marked difference between the amount which percolates from different soils under conditions of bare fallow, that is, quite apart from any effect which crops will have. With 20″ rainfall, the Rothamsted soil gave 6″ of drainage, the Cawnpore soil 3″, and with 22″ of rain the Pusa soil none. These differences are not perhaps very marked. With 41″, the Rothamsted soil yielded 25″ ; with 46″ of rain (of which about 4″ ran off) the Cawnpore soil yielded 21″ of drainage ; with 40″ the Pusa soil yielded 7″ or 8″ of percolation. Here the differences are much more striking. In a measure the markedly less drainage at Pusa is accounted for by surface drainage ; for whilst not more than 2″ of water can collect at any one time on these gauges, the coping stones of the Rothamsted and Cawnpore gauges may hold up a number of inches of rain water. But a more potent factor is the amount which annually evaporates. At Rothamsted this varies from 13″ to 16″ ; at Cawnpore it is between 16″ and 20″ ; at Pusa about 28″ per annum. The soil which loses most water in this manner will absorb a larger amount of rainwater before yielding drainage than the soil which loses less by evaporation.

These figures may be considered to provide an index of how much water percolates through good and well cultivated soils of the Indo-Gangetic alluvium, of which those at Cawnpore and Pusa are examples. But the data are probably quite insufficient to give an idea of what occurs in other soils such as a Black Cotton Soil, for it is to be recollected that although the latter soils allow water to drain through them freely, they hold very large amounts of water, and nothing definite is known regarding the amount of water they lose by simple evaporation during dry weather.

Drainage from cropped land.—The drainage conditions of land bearing crops have been recognised as generally different from that

of bare fallow. The presence of a crop protects the surface of the soil and hinders direct loss of water by evaporation, but the crop itself transpires large amounts of water which are taken up by the root system, from the sub-soil. It is evident therefore that the resulting effect on drainage will depend on the relative effect of the above two factors. The literature of the subject is not very exhaustive. Experiments were carried out for a long series of years by Greaves near London(4) where the following average figures were obtained :—

Soil.	Rainfall. Inches.	Percolation. Inches.	Evaporation and transpiration. Inches.
Fine gravel	25·7	21·5	4·2
Turfed soil	25·7	7·6	18·1

The soil was 3ft. deep. But since the material of the earth of these gauges was dissimilar, the figures are not comparable. Nor are data available showing the weight of grass produced, which is an all-important matter.

At Grignon, near Paris, similar experiments were conducted between the years 1892-7 by Dehérain in a number of gauges (twenty), which consisted of cement tanks into which the excavated soil of the site had been refilled ; the surface and sub-soil being placed in the tanks in their natural relative positions.(5) The soil of several of these gauges was maintained fallow, whilst on the majority various crops were cultivated. The effect of these crops on the amount of drainage varied, but in the year 1896-7, of which the quoted records are the most complete, the amount of drainage water was from about three-fourths down to one-half of that from the fallow gauges. Thus at Grignon the effect of the crop was very much less marked than in Greaves' experiment.

(4) Warington's Physical Properties of the Soil, p. 122.

(5) For a description of these investigations reference should be made to "Traite de Chimie Agricole," par M. Dehérain, pp. 584-99.

Some of these records are set out graphically in Chart No. III on page 96.

As previously mentioned, two of the Pusa gauges, Nos. II and IV, have been cropped throughout. From the time of construction until the hot weather of 1908 the original grass was allowed to grow. Then the turf was dug up and the soil got ready for maize ; after the first heavy rain in June a dressing of superphosphate (= 50 lbs. soluble P_2O_5 per acre) plus calcium nitrate (= 50 lbs. N per acre) was given and maize sown. The monsoon was unusually weak and the maize had to be re-sown on July 8th. Finally, a moderate crop was realised. Following this, wheat was sown on 3rd November which proved to be only a very small crop. After harvesting this in March, the soil was tilled and left fallow during the months April to June 1909, when maize was again sown, after suitable tillage, but without manure, on June 21st. This crop was in weight very similar to that of 1908. In November 1909 the soil was again cultivated, and superphosphate plus calcium nitrate, of the same quantity as in June 1908, were mixed into the surface soil. Wheat was then sown. For several reasons it was desired to encourage this wheat crop so as to obtain as heavy a crop as possible ; and for this purpose one inch of water was applied in the first week of January 1910. Partly owing to this additional water, and partly to the much more liberal monsoon which would leave the soil better supplied with moisture in October 1909 than in October 1908, and doubtless also in part owing to the freshly given manure, this object was realised, and this wheat crop amounted to about twelve times the weight of the corresponding crop of 1908-9. It was harvested at the end of March. The soil was then roughly cultivated and allowed to remain fallow during the remainder of the hot weather. On June 17th, 1910, maize was again sown (without further manure) and this proved to be a very similar crop to those preceding it.

At Cawnpore Juar was grown on gauges Nos. I and IV in the monsoon period of 1909 and maize in 1910.

The details regarding the several crops are set out in statement No. XV from which the following have been taken :—

Crop.		Weight. lbs. per acre.	Estimated water transpired. Inches.
	Pusa.		
1908	Maize	4,700	6·2
1908-9	Wheat	610	2·3
1909	Maize	4,100	5·5
1909-10	Wheat	7,200	11·1
1910	Maize	4,700	6·2
	Cawnpore.		
1909	Juar	No. I 6,945 No. IV 3,487	9·2 4·6
1910	Maize	1,830	2·4

As has been briefly mentioned, the effect which these crops would have on the amounts of drainage and evaporation would be the result of several factors. (i) The amount of water transpired depends largely on the weight of the crop. Each crop has been shown (6) to possess a transpiration ratio peculiar to itself, but the variations in the magnitude of such ratios are generally small compared with differences in the weight of crops. (ii) A growing crop protects the soil moisture more or less from evaporating into the air ; the normal circulation of the air over the soil is retarded and the air within the crop is thus maintained in a highly saturated condition ; at the same time the plant reduces the amount of water in the surface soil. The protective effect of a crop against direct evaporation may be estimated approximately from the data we have. It may be expressed as inches of water and will be designated by the letter P.

It is evident that the quantity of water found to have evaporated from the fallow gauges will be less or greater than that evaporated and transpired from the cropped gauges, according as the effect of protection is less or greater than the transpiration. For example, the amount evaporated and transpired from gauge IV (Pusa) in 1909-10 was 30·9″, whereas that evaporated from gauge III (fallow)

(6) These Memoirs, Nos. 8, and 10.

was 25·8″. In this case the effect of transpiration was greater than protection by 5·1″.

Using the available data we have two periods, namely, 1907-9 (there being no drainage in 1908, it is necessary to combine the two years' data) and 1909-10. Taking the first period, we have :—

	Inches.
Mean evaporation from gauges I & III	59·2
Do. and transpiration from gauges II & IV ..	58·8
	·4

Thus during this period the effect of P was approximately equal to T, the amount transpired by the grass and the three crops. The latter three are estimated to have transpired 14″. Taking the second period we have :—

	Inches.
Mean evaporation from gauges I & III	25·9
Do. and transpiration from gauges II & IV ..	31·6

Here, owing to the fact that one inch of irrigation water was given to the wheat in January 1910, one inch should be added to the quantity registered in statement No. III as evaporation and transpiration. Thus we have 31·6 + 1·0 = 32·6″. T was therefore greater than P by 6·7″. The crops are calculated to have transpired 17·3″ and hence P = 17·3—6·7 = 10·6″.

The value of P = 14″ obtained for the first period is probably too low, because nothing is known of how much the grass of the cold weather 1907-8 transpired. It was very poor grass and can hardly have transpired so much as the wheat (a very poor crop) did in 1908-9 and which was 2·2″. Since we can only hope to obtain an approximate idea of the real value of P, 2″ may be added to the 14″ already accounted for, which gives P the value 16″ for two years.

Also in 1909-10, since no drainage was obtained from No. II gauge, all that is known is that evaporation and transpiration was at least equal to the rainfall (= 32·2″) and may have been a trifle higher. Judging however from No. IV gauge it could not have been very different.

We may next compare these values with the normal evaporation from fallow soil of the two periods *rabi* and *kharif*. The Pusa soil moisture records show that the evaporation during the *rabi* period, November 15th to March 31st, is about 6″. That for the dry period from about November 1st to May 31st, that is, to the commencement of the following monsoon = 10″. The drain-gauges show that the annual evaporation from bare soil = 28″ and hence the evaporation during the monsoon period is about 18″. Thus the total evaporation from fallow soil during the two periods of growing crops = 18″ + 6″ = 24″. The value of P for the two years 1907-9 = 16″ or, since the crops were very similar in size, 8″ per annum, that is about $\frac{8}{24}$ or $\frac{1}{3}$. This means that the effect of the crops was to reduce direct evaporation to about $\frac{2}{3}$ on cropped land of what would occur from bare fallow.

In 1909-10 P = 10″, and hence in this case the mean effect was to reduce direct evaporation to $\frac{3}{5}$ of what it would have been from fallow soil. It is to be noted that these values for P are nearly equal.

We may next try to apportion the effect to the individual crops. Taking first the *rabi* period (that is, November to March) during which the grass of 1907-8 and wheat of 1908-9 respectively grew, into consideration, it is improbable from a knowledge of the crops, that the grass or the wheat could have afforded much protection, for they were both very small. If it is assumed that they reduced direct evaporation to $\frac{5}{6}$ of that on bare soil, then P = $\frac{1}{6}$ which is equal to about 1″ of water for each crop—grass and wheat. Thus 14″ are left for distribution among the two maize crops. These were approximately equal in size, and hence we arrive at the figure 7″ as the effect of protection by each. This is equal to about $\frac{7}{18}$, indicating that direct evaporation was reduced by the maize to nearly two-thirds of what it would be from bare soil. If it is next assumed for 1909-10 that the maize crop, which was very similar to those of 1908 and 1909, protected evaporation in a like degree, P = 7″ and since the total value of P for the wheat and maize was 10·6″, there remains 3·6″ as the measure of protection by the

wheat crop. The normal direct evaporation = 6″ and we thus obtain approximately $\frac{1}{2}$ as the measure of protection for the wheat of 1909-10, that is, it reduced evaporation to one-half of what it would have been from bare soil. These considerations at the same time explain why as much drainage was obtained from the cropped gauges in 1909 as from the fallow gauges, whilst in 1910 less was obtained from the former than from the latter. At Pusa the chief controlling factor was the *rabi* crop (wheat), but the circumstance will vary in this respect within wide limits at different places.

The corresponding deductions from the Cawnpore data are less dependable, in part because there have been much fewer crops, in part because we know much less about the amount of water lost during the dry season. The crops in these gauges were, unlike those at Pusa, so different in weight that they have to be considered separately. The difference in amount evaporated from gauges I and II respectively, was in 1908-9, 3·3″, that is, transpiration was greater than "protection" by this amount; the crop is estimated to have transpired 9·2″; whence the value of P = 5·9″. The difference between amounts of evaporation from gauges IV and III was ·3″; the *juar* is estimated to have transpired 4·6″, whence P = 4·3″. The crops on these gauges in 1910 were so small as to be useless for the end in view. That the value for "protection" by the *juar* on gauge No. I should have been greater than on gauge IV was to be expected because the former was a larger crop. So far as can be estimated at present, the evaporation from bare soil during the rains at Cawnpore is about 14″, so that the *juar* crops may be said to have reduced simple evaporation to about $\frac{1}{2}$ or $\frac{2}{3}$ of what it is from bare soil.

The maximum amount of water which drains per day.—During periods of heavy rain the amount of water passing through the gauges becomes naturally very large and has occasionally aggregated 4″ in 24 hours. Thus at Pusa for the 24 hours concluding on the morning of August 8th, 1909, No. II gauge yielded 4·375″ and No. IV, 3·829″ and on August 31st No. IV yielded 3·156." Other large

amounts are 2·7″ on June 17th, 2·8″ on June 29th, 2·3″ on July 22nd, 2·2″ on August 8th all from No. IV; 2·3″ on June 22nd, 2·2″ on October 1st from No. III. Amounts varying from between 1″ and 2″ were obtained on no less than 36 occasions from one or other of the gauges in that year of heavy rain.

The amount of surface drainage.—Of all the features of drainage the amount of water which runs off the land during *heavy* rain is the most variable, and one may at once admit the impossibility of reducing its quantity to any general statement.

One of the most important factors affecting the quantity of surface drainage is the state of the surface soil. If this has been freshly ploughed and no rain or only light rain has recently fallen, 4″ of rain may fall in 24 hours without any running off. An instance of this came under my observation in 1907. On the other hand, if land has not been recently tilled, some portion of the first half inch of rain will probably run off. Between these extremes we have the land-bearing crops, which will take up large amounts if the surface has not been trodden and if rain has not recently fallen, but will absorb much less if labourers have been through the crop or if the surface soil is very wet. As has been mentioned, such a soil as that at Pusa or Cawnpore can absorb more than 2″ of rain per 24 hours for at least some time, provided the surface is tilled.

Another factor is not only the amount of rain per 24 hours, but the amount falling per hour. There are very few records regarding this point. The following have been kindly communicated to me by Dr. Simpson of the Indian Meteorological Department. At Galveston on June 4th, 1871, 2·54″ in 14 minutes; at Preston, England, on August 10th, 1893, ·80″ in 5 minutes; at Lane (Saxony) on June 5th, ·76″ in 6 minutes.

In order to obtain data which would fix our ideas on the subject, a self-recording rain-gauge was fitted up at Pusa in 1907 from the curves of which the amount falling per unit of

time was estimated. The following were the largest quantities recorded :—

Date.	Time.	Amount.	Inches per hour.
August 24th	3-15 to 4	·90″	1·20
,, 28th	14-15 to 15	·60″	·80
,, 29th	17-0 to 17-45	·98″	1·31
,, 31st	12-0 to 13-30	2·45″*	1·63
August 31st to Sept. 1st	22-30 to 2-30	4·80″*	1·20
September 1st	3-25 to 3-50	·67″*	1·62
,, 3rd	14-10 to 15	1·18″	1·42
,, 9th	15-15 to 15-35	·60″	1·82

Of these the best example is the rainfall of August 31st to September 1st. Rain fell during the 24 hours without any cessation, and included the three falls marked above with an* ; that is, the fall consisted principally of three heavy showers. A rate of 2″ per hour seems to be very uncommon.

Statement No. IV.

Details of rainfall and surface drainage during 1909.

Date.	Rainfall. Inches.	Surface Drainage.			
		Gauge I fallow. Inches.	Gauge II maize. Inches.	Gauge III fallow. Inches.	Gauge IV maize. Inches.
June 4th	·33	..	..	..	..
,, 7th	1·55	..	..	..	..
,, 8th	1·00	..	..	—	..
,, 9th	3·55	..	..	..	..
,, 10th	5·43	·137	*Nil*	·035	*Nil*
,, 11th	·85	*Nil*	*Nil*	*Nil*	*Nil*
,, 12th	2·97	·453	·040	·075	*Nil*
,, 16th	2·09	*Nil*	*Nil*	·011	*Nil*
,, 17th	3·98	1·814	·064	·750	·123
July 21st	2·16†	·115	·024	·046	·102
,, 22nd	1·72†	1·142	*Nil*	*Nil*	*Nil*
August 3rd ..	1·70	..	..	..	..
,, 4th ..	·08	..	..	..	..
,, 5th ..	·08	..	..	..	..
,, 6th ..	1·64	..	..	..	..
,, 7th ..	4·42	1·629	·088	·482	·314
,, 8th ..	4·59	2·356	·343	3·425	2·688
,, 30th ..	·60	*Nil*	*Nil*	*Nil*	*Nil*
,, 31st ..	4·09	·346	·389	·222	·445
September 30th ..	1·13	..	..	..	..
October 1st	2·27	·330	·295	·295	·464

† This fall was a continuous one from 11 P. M. on 21st until 10 A. M. on 22nd.

Although the amount of surface drainage is a widely varying factor, this is not a sufficient reason for entirely neglecting an opportunity to measure its magnitude, especially when such an estimate may be made under well defined conditions. It was for this reason that overflow pipes and measuring tanks were added to the Pusa gauges when these were constructed in 1906. There are three pipes to each gauge, fixed at 2″, 3″ and 4″ above ground level, respectively, and which empty into a side tank, of which each gauge has one. Each pipe is fitted with a tap, so that 2″, 3″ or 4″ of rain can be held up on the gauges at will. Up to the present all the taps have remained open, so that any rain water which has collected during wet weather in excess of 2″ deep on any gauge has run off into the side tank. The *annual* data are included in Statement No. III. In Statement No. IV are set out the *details* for 1909. A consideration of these data shows that the quantities of water which so run off vary within comparatively wide limits. Some of the variations are what one would expect. Thus No. I gauge is 6ft. deep and the lower 2ft. is clay, whereas No. III gauge is 3ft. deep and has no clay in it. These are the fallow gauges. Accordingly it is to be anticipated that water will pass more readily through No. III, and hence during heavy storms less water will be held up on this gauge and it will give less surface drainage than No. I, which expectation has been generally realised when the rainfalls were sufficiently heavy to cause surface drainage at all. During periods of light rainfall both gauges will behave alike, the drainage water from No. I merely requiring rather more time to percolate. But the amount of surface flow from the other two gauges which have been cropped has not been altogether what one would have anticipated. No. II has absorbed water more freely during heavy storms than No. IV. These differences are, however, of less importance than the question whether the quantities found, approximate at all to what generally occurs in the field. I have often examined fields during or immediately after heavy rain, and it seems to be a common feature to have more than 2″ of water collected on cultivated land so that the fact of the overflow pipes being 2″ above the

ground level can hardly be objected to. There is also nothing unusual in the state of the surface soil of these gauges, except that they are not allowed to get consolidated. And after considering all the several factors which affect the question, the conclusion seems reasonable that the amounts which have overflowed from these gauges are of the same order of magnitude as those which occur generally. The practical agriculturist may be surprised at their smallness, and he will point to the large volumes of water which run off the land during storms in support of the doubt which he entertains of the correctness of these estimates. But let him calculate the volume of water which say 1″ of surface drainage into any of his main drains is equal to, and add to this the much larger proportion of the rainfall which naturally runs off all roads and buildings and hard uncultivated land into the same drains, and he will then probably admit that his eye-estimate has been faulty.

The amount of evaporation at the two stations.—The amount of annual evaporation is exhibited in Statements Nos. II and III. At Cawnpore it has been about 18″ from the two six-foot gauges when fallow and about 16″ from the two three-foot gauges under like conditions ; or in comparison with the annual rainfall, rather more than one-half. At Pusa the annual evaporation has been much greater, namely, about 28″ or about $\frac{2}{3}$ of the rainfall.

PART III.

Combined Nitrogen in Drainage Water.

The amount of nitrate and ammonia in the drainage waters.—Average samples of the water which has drained through the gauges at *Cawnpore* have been analysed once a fortnight since they were first constructed, though for reasons previously (p. 76) given, the records for Nos. II and IV were delayed by two years and one year respectively. The nitric nitrogen has been determined in these samples by the Schloesing method. At first the ammonia was also determined, but as this constituent proved to be present in as small quantity as was found in the Rothamsted drainage water, its determination was subsequently discontinued. At *Pusa* the drainage water has been analysed every day. Here also the amount of ammonia was found to be as negligibly small as at Cawnpore and the determination was discontinued until 1910. After obtaining the peculiar results in respect of nitrate in the drainage from the cropped gauges to which reference will be made, it was decided to again determine the ammonia, but the experience of 1910 has shown it to be present in such drainage in similarly negligible quantity. The nitrate in the daily drainage has been determined by the phenol-disulphonate method. From the daily drainage, average samples have been made weekly or fortnightly, or for particular rainfalls as in 1910, and the nitrate determined in these by the Schloesing method. Thus the nitrate has been determined by two independent methods in the Pusa water.

Details of these analyses are set out in Statements Nos. IX to XIV (at end of Memoir) and the annual quantities are collected together in Statements Nos. V and VI. The quantities of nitrate are expressed as parts of *Nitrogen* throughout, a mode of expression which has been common to discussions of this subject, but it must

be recognised that the weight of nitrate is in reality several times that of its nitrogen.

Bare fallow land.—Confining the attention in the first instance to the drainage from *bare fallow* soil, *i.e.*, all the four Cawnpore gauges until 1909 and Nos. I and III Pusa gauges, two facts become evident:—

(i) The quantity of nitrate (lbs. per acre) varies largely with the season, having been over 100lbs. and even as much as 200lbs. per acre in individual years of heavy rainfall at Cawnpore and even more than this at Pusa, whilst in years of small rainfall the amount falls to a very nominal quantity. This matter will be discussed subsequently (Part IV).

Statement No. V.

Annual amount of nitrogen as nitrate in drainage water obtained from the Cawnpore gauges.

Year.	Rainfall. Inches.	Drainage. Inches.	Nitric Nitrogen.	
			Parts per million.	lbs. per acre.
Gauge No. I.				
Nov. 1st 1903 to Oct. 31st 1904 ..	46·51	21·22	21·6	106·5
,, 1904 ,, 1905 ..	20·61	3·14	10·3	7·4
,, 1905 ,, 1906 ..	36·49	19·13	41·6	180·3
,, 1906 ,, 1907 ..	20·89	3·65	11·6	9·6
,, 1907 ,, 1908 ..	32·66	14·56	40·0	102·4
,, 1908 ,, 1909 ..	37·53	13·16*	6·6	27·2
,, 1909 ,, 1910 ..	28·35	4·53*	1·5	1·5
Gauge No. II.				
Nov. 1st 1903 to Oct. 31st 1904 ..	..	..	..	..
,, 1904 ,, 1905 ..	..	..	..	..
,, 1905 ,, 1906 ..	36·49	16·84	53·0	200·5
,, 1906 ,, 1907 ..	20·89	4·83	12·6	13·8
,, 1907 ,, 1908 ..	32·66	14·41	32·5	106·3
,, 1908 ,, 1909 ..	37·53	16·47	12·6	61·8
,, 1909 ,, 1910 ..	28·35	7·37	13·9	23·3

* Juar was grown during monsoon.

Year.	Rainfall. Inches.	Drainage. Inches.	Nitric Nitrogen. Parts per million.	Nitric Nitrogen. lbs. per acre.
	Gauge No. III.			
Nov. 1st 1903 to Oct. 31st 1904 ..	46·51	22·48	11·1	56·7
,, 1904 ,, 1905 ..	20·61	2·93	26·8	17·8
,, 1905 ,, 1906 ..	36·49	18·24	14·7	60·7
,, 1906 ,, 1907 ..	20·89	5·92	24·1	32·5
,, 1907 ,, 1908 ..	32·66	15·61	18·3	64·7
,, 1908 ,, 1909 ..	37·53	16·47	9·8	46·5
,, 1909 ,, 1910 ..	28·35	8·09	18·7	34·4
	Gauge No. IV.			
Nov. 1st 1903 to Oct. 31st 1904 ..	..	..	..	..
,, 1904 ,, 1905 ..	20·61	3·57	29·2	23·6
,, 1905 ,, 1906 ..	36·49	19·94	18·5	85·6
,, 1906 ,, 1907 ..	20·89	6·80	24·0	37·2
,, 1907 ,, 1908 ..	32·66	16·18	15·6	57·2
,, 1908 ,, 1909 ..	37·53	16·15*	6·5	24·8
,, 1909 ,, 1910 ..	28·35	6·23*	·7	1·0

Comparison of these data is rendered a little difficult because on the one hand two of the gauges have not yielded records for the whole seven years, whilst on the other hand crops have been grown during the last two monsoons on two gauges. The following comparison is perhaps the best:—

Gauge No.	Nitric nitrogen lbs. per acre. I	II	III	IV
	Fallow.	Fallow.	Fallow.	Fallow.
Average of 5 years 1904-8	81·2	..	46·5	..
Average of 3 years 1906-8	97·4	106·8	52·6	60·0
	Cropped.	Fallow.	Fallow.	Cropped.
Average of 2 years 1909-10 ..	14·3	42·5	40·5	12·9

* Juar was grown during monsoon.

Statement No. VI.

Annual amount of nitrogen as nitrate in drainage water obtained from the Pusa gauges.

Year.	Rainfall. Inches.	Drainage. Inches.	Nitric nitrogen. Parts per million.	Nitric nitrogen. lbs. per acre.
Gauge No. I (Fallow).				
Novr. 1st 1906 to Octr. 31st 1907 ..	39·72	6·96	12·62	19·94
,, 1907 ,, 1908 ..	21·92	*Nil*	*Nil*	*Nil*
,, 1908 ,, 1909 ..	75·70	28·39	40·58	261·54
,, 1909 ,, 1910 ..	32·30	6·41	11·72	17·06
Mean ..	42·41	10·44	..	74·64
Gauge No. II (Cropped).				
Novr. 1st 1906 to Octr. 31st 1907 ..	39·72	4·64	·04	·04
,, 1907 ,, 1908 ..	21·92	*Nil*	*Nil*	*Nil*
,, 1908 ,, 1909 ..	75·70	32·48	6·93	51·12
,, 1909 ,, 1910 ..	32·30	*Nil*	*Nil*	*Nil*
Mean .	42·41	9·28	..	12·79
Gauge No. III (Fallow).				
Novr. 1st 1906 to Octr. 31st 1907 ..	39·72	8·77	8·54	17·00
,, 1907 ,, 1908 ..	21·92	*Nil*	*Nil*	*Nil*
,, 1908 ,, 1909 ..	75·70	34·76	26·57	209·57
,, 1909 ,, 1910 ..	32·30	6·49	24·85	36·61
Mean ..	42·41	12·51	..	65·79
Gauge No. IV (Cropped).				
Novr. 1st 1906 to Octr. 31st 1907 ..	39·72	9·08	·01	·02
,, 1907 ,, 1908 ..	21·92	*Nil*	*Nil*	*Nil*
,, 1908 ,, 1909 ..	75·70	39·57	6·00	53·88
,, 1909 ,, 1910 ..	32·30	1·38	1·18	·37
Mean ..	42·41	12·51	..	13·57

(ii) The second noticeable fact is the very large amount of nitrate which has been found in these waters as compared with the experience at Rothamsted. It has been generally assumed that, owing

to the higher temperature enjoyed by Indian soils, nitrification will be more rapid in this country and large amounts of nitrate in drainage waters might on this account cause no particular surprise. This was so at least at Cawnpore, because prior to the construction of the gauges the land had been regularly manured (*vide* p. 67). The average annual quantities of nitric nitrogen have been at Cawnpore about 80 lbs. and 100 lbs. from the two 6ft. gauges respectively, and 50 to 60 lbs. from the two 3ft. gauges. The very large amounts of nitrate which have been obtained in some years are presumably not the produce of one year's nitrification, but of two, the drainage of the first year having in each case been insufficient to remove its nitrate. In regard to the Pusa soil, considering the previous history of the land, that the amount of organic matter is only small, and more particularly the fact that it contained practically no nitrate when the gauges were made, the amount found in the water, namely, an average of 75lbs. nitric nitrogen per annum from No. I and 66 lbs. from No. III is greater than was expected.

Cropped land.—Turning next to the *gauges bearing vegetation*, the attention is directed primarily to the Pusa record. On gauges Nos. II & IV the original grass was maintained until May 1908. As the record shows, practically no nitrate was found in the drainage-water so long as the grass grew. The quantity received from the fallow gauges was not very great in 1907 and it was assumed that the absence of nitrate in the drainage from Nos. II & IV was due simply to the fact that it was assimilated by the grass as fast as it was formed.

The nitrate data obtained in 1909 showed that this is not a complete explanation. Were it so, then, given a rainfall so plentiful as to " wash out " the soil of the gauges thoroughly, the amount of nitrate in the drainage-water from a fallow gauge should be equivalent to that in the drainage from a cropped gauge plus the nitrogen in the crop, on the assumption that the whole of the latter is derived from nitrate. The following statement sets out the quantities of

nitrogen in pounds per acre which can be accounted for during the period 1907-9 :—

Gauge No.	I	II	III	IV
Nitric nitrogen in drainage-water ..	+ 261·5	+51·1	+209·6	+53·9
Nitrogen in manure used in June 1908	..	—50·0	..	—50·0
„ in maize crop 1908 ..	..	+49·0	..	+44·7
„ in wheat crop 1908-9 ..	..	+7·9	..	+7·9
„ in maize crop 1909 ..	..	+38·6	..	+31·2
„ *estimated to have been in roots of the three crops ..	..	+31·8	..	+27·9
Net total ..	+261·5	+128·4	+209·6	+115·6

Had there been as much nitrate formed in the soil of gauges II & IV as in I & III, the totals obtained in the foregoing statement should have been equal or approximately so ; there is, however, a great deficiency in Nos. II & IV. It is only seldom that one can obtain data such as these, because if the rainfall is insufficient to

* The amount of nitrogen in the root system has been calculated from some determinations of the roots of wheat plants obtained in pot cultures. After harvesting the plants, the root was separated from the soil by mixing the whole with liberal amounts of water, and separating with a fine sieve. The data are given since so little information on this subject exists.

	Jar No.	71	72	73
1.	Weight of dry matter of above-ground growth (grms.)	35·3	136·1	102·1
2.	Nitrogen in dry matter (grms.)	·532	1·540	1·225
3.	Roots, sand, etc., which remained on sieve (grms.)	58·0	49·5	33·5
4.	Organic matter in Roots, etc. (grms.)	16·79	24·84	20·01
5.	Nitrogen in this organic matter (grms.) ..	·402	·511	·417
6.	$\frac{\text{Root-Nitrogen}}{\text{Organic matter in roots}}$	·024	·021	·021
7.	$\frac{\text{Root-Nitrogen}}{\text{Above-ground nitrogen}}$	·75	·33	·34

Since the soil used for the pot cultures could not be freed from organic débris at the commencement in the same perfect manner as that employed at the conclusion of the experiment, the whole of the organic matter separated, and hence also its nitrogen, did not belong to the root system of the wheat plants. Consequently the ratios are undoubtedly too high, *i.e.*, the ratio of nitrogen in roots to nitrogen in above-ground growth was certainly less than $\frac{1}{3}$. Judging by the data from jar 71 (unmanured, small plants) in comparison with those of Nos. 72 and 73 (large plants) the amount of organic débris other than new roots was large. However, since for the purpose of our drain-gauge data it is better to over-estimate rather than to under-estimate the amount of nitrogen in the roots, the proportion between the nitrogen in the roots and the above-ground growth, respectively, has been taken as $\frac{1}{3}$.

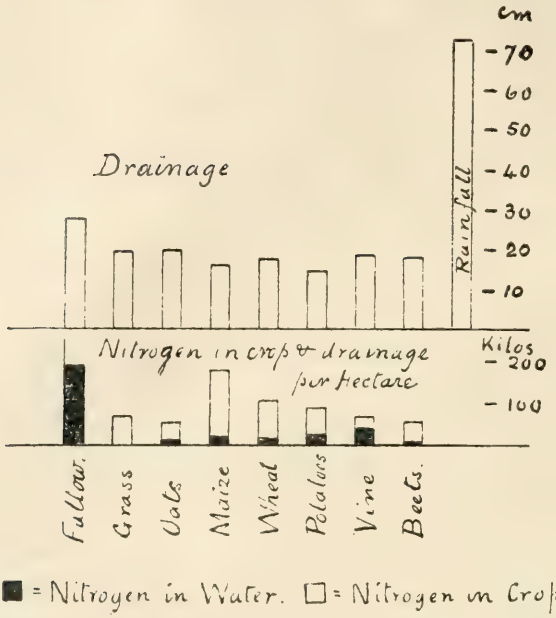
completely wash the gauge out, any differences in the amounts of nitrogen in the drainage water may be attributed in part to assimilation by the crop and in part to nitrate remaining in the gauge. The rainfall of 1909 was, however, so copious as to entirely replace the whole of the water in a 6ft. gauge once, and to replace it in a 3ft. gauge *twice*. The nitrate figures of the drainage water also demonstrate this. (Compare Statement XII).

At Cawnpore the cropped gauges yielded less nitrate than the fallow gauges, but the rainfall was not sufficiently heavy to wash the gauges out perfectly enough to admit of deductions such as those at Pusa do. The smaller amount of nitrate in the drainage from the cropped gauges could be just as well accounted for by crop assimilation coupled with an allowance for nitrate remaining in the gauge.

A similar remark applies to both stations in 1910.

The records of drainage obtained at Grignon, to which a reference has been made (p. 79) indicate similarly that the crop exerts an indirect effect on the amount of nitrate formed. In Chart No. III are set out graphically some of Dehérain's results. In the upper part are the relative quantities of drainage water, in the lower, the amount of nitrogen found (*a*) in the crop and (*b*) in the drainage water. The total amount of nitrogen so found in crop and water was, in most cases far less than the nitrate in the drainage from the fallow soil. To a certain extent this is accounted for by the somewhat smaller amount of drainage, as also by the fact that the drainage was probably insufficient to wash the soil of the gauge out completely. But after making all reasonable allowance for the effect of these factors, the nitrogen deficiencies in the gauges bearing grass, wheat, potatoes, vines and beetroot is so great that some other explanation seems to be necessary than that the remaining nitrate was merely not washed out.

CHART III.



More recently, too, Lyon and Bizzel(7) have published results of some records of the amount of nitrate in soils bearing crops from which they conclude that higher plants may exert in some cases a stimulating or in others an inhibitory effect on nitrification.

The 1909 record at Pusa is very striking. The smaller amount of nitrate found in the drainage from the cropped gauges may be due to one or all of three possible causes.

(i) That denitrification occurs concurrently with nitrification. This cause may be excluded on the ground that denitrification is known not to take place appreciably in the presence of oxygen, and other work in progress at Pusa has shown that a plentiful supply of oxygen must have been present.

(ii) That there was a very considerable assimilation of nitrate by some lower organism which was present in the cropped land to a much greater extent than in the fallow land.

(iii) That the presence of the higher plant prevented, either directly or indirectly the formation of nitrate.

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(7) Effect of crops in nitrification by Lyon and Bizzell, Jour. Franklin Inst., 1911.

Whilst the second explanation is a possible one, calculation shows that a very considerable growth of such an organism would be necessary in order to account for such a large defect in the amount of nitrate as that recorded at Pusa in 1909. The third explanation is one which is much easier to understand and is the more likely. As a matter of fact, a chapter on bacteriology is here approached which has so far received little attention. While the action of lower organisms on higher plants has been in part studied, the converse problem, namely, the effect of higher plants on lower organisms has remained largely unnoticed. For example, we are practically ignorant at the present time of the extent to which the bacterial flora in the soil is related to the crops grown.

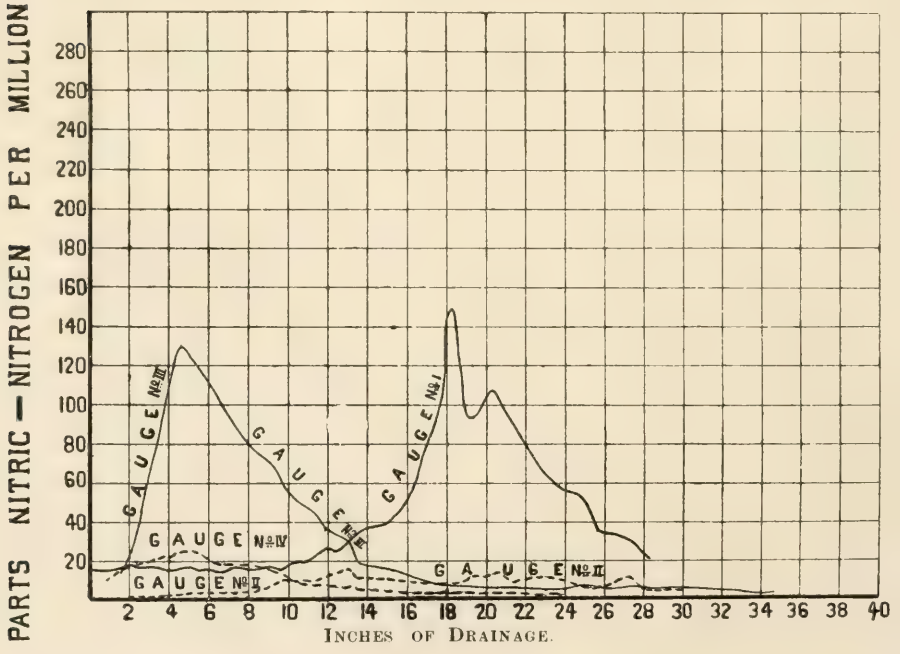
The undesirability of speculating too freely on the subject is obvious, but in the light on newer work (8) on biological associations in the soil, the Pusa data will no doubt appeal to all those who are specially interested in this department of soil investigation, and the subsequent history of the Pusa and Cawnpore gauges should be of value.

The period when most nitrate leaves the gauges.—From the record of nitrate, as set out in Statements Nos. IX—XIV the period when the greater part of the nitrate passed out of each gauge is very clearly shown. If the monsoon approximates to the normal the major part of it passes out of the 3ft. gauges much earlier than from the 6ft. gauges. The best example to use in illustration of this fact is the Pusa record for 1909, Statements IX and XII. The comparison may be made either with the period of the season, as in the statements, or by plotting the nitrate against the drainage as in the Chart No. IV. It will be understood that for simplicity's sake, the nitrate record is stated in terms of nitrogen per acre. Following the sequence of events as shown in Statement No. XII it is seen that from No. III gauge no less than 145lbs. came out with the first 23″ of rain in June, which was followed by 39lbs. with the rain which fell at the end of June and first days of July. Subsequently to this the quan-

(8) See Russell and Hutchinson, J. Ag. Sci., Vol. III, p. 111.

tities of nitrate from this gauge were comparatively small. The course of events in respect of the No. I gauge was quite different. Some nitrate, and not altogether small amounts, passed out regularly with each rainfall during June and July, but the major part of the nitrate came out of this gauge in August and September ; 87lbs. of nitric nitrogen during the first three weeks of August and 117lbs. during the last week of August and first week of September. Very similar relations held in respect of the gauges IV and II respectively; the major part of the nitrate came out of gauge IV in June ; that of the No. II gauge was more uniformly distributed, but its maximum occurred at the same period as that of No. I gauge.

The Chart No. IV shows these relations also very graphically:



In it, the two continuous curves refer to the fallow gauges Nos. I and III, whilst the broken lines refer to the other two on which maize grew. In plotting these curves, only *appreciable* quantities of drainage have been taken into account, because the scale would not admit of the registration of the minute quantities, ·0005″ and the like,

which find a place in Statement No. XI. Hence the highest concentrations of nitrate do not appear. A glance at this chart shows that the concentration of nitrate from gauge III (3ft.—fallow) rose rapidly to a maximum of about 130 parts N. per million, and that the greatest concentration occurred in the drainage between the 3rd and 10th inches, after which the water was comparatively free from nitrate.

From gauge No. I (6ft.—fallow) the concentration remained comparatively small until about 15″ of water had come through, when it rose rapidly, attained a maximum of about 150 parts when 18″ had come through, after which it declined rapidly again.

From gauge IV (3ft.—maize) the concentration rose quickly, like No. III, and attained its maximum of about 25 parts N. when 5″ had come through, after which it fell again. From gauge II there were maximum concentrations when 13″ and 20″ had come through, though in this case the variation of concentration was only small.

These curves also show how great was the difference in the concentration of nitrate from the fallow and from the cropped soil respectively, a point which has been already dealt with (p. 93). It will be appreciated that the reason why the major part of the nitrate from the 3ft. gauges escaped so much earlier than from the 6ft. gauges was because, at the commencement of the monsoon, it was situated much nearer the two bottom of the 3ft. gauges than to the bottom of the 6ft. gauges.

The period when nitrification is most active.—The Pusa data of 1909 were the most striking of any which had been obtained in India. In other years the nitrate had passed out of the gauges more or less as one would anticipate on the assumption that a certain quantity was present in the upper soil, about the 2nd foot, which was removed by the descending water, but it had generally happened that there was no very definite evidence that all the nitrate of the hot weather had been removed during the monsoon, or that what was removed was not largely formed during wet weather. But the monsoon of

STATEMENT VII.

Amount of Nitrate in soils after harvest (Parts Nitrogen per million of soil).

	Fallow land.	After Wheat (Manured).	After Wheat (Unmanured).	After Linseed (Manured).	After Mustard (Manured).
Date of harvest ..		23–3–10	28–3–10	21–3–10	7–3–10
Date of sampling ..	4–4–10	6–4–10	8–4–10	18–4–10	11–4–10
Depth.					
0″— 6″	·66	·16	trace	·46	·25
6″—1′ 0″	·52	..	·31	..	..
1′0″—1′ 6″	·46	..	..	..	..
1′ 6″—2′ 0″	·69	..	..	..	..
2′ 0″—2′ 6″	·48	..	..	..	..
2′ 6″—3′ 0″	·59	..	..	..	..
3′ 0″—3′ 6″	·62	..	..	·24	·17
3′ 6″—4′ 0″	·60	..	..	..	..
4′ 0″—4′ 6″	·80	..	..	..	·20
4′ 6″—5′ 0″	·42	..	..	..	..
5′ 0″—5′ 6″	·62	trace	..	·25	..
5′ 6″—6′ 0″	·49	·36	·32	trace	..
6′ 0″—6′ 6″	·40	·28	trace	..	24
6′ 6″—7′ 0″	·40	·47	trace	·24	trace
7′ 0″—7′ 6″	·48	·64	·29	·26	·39
7′ 6″—8′ 0″	·22	·92	·51	..	·41
8′ 0″—8′ 6″	·22	·68	·40	·20	·39
8′ 6″—9′ 0″	..	trace	..	·43	trace

STATEMENT NO. VIII.

Amounts of Nitrogen in Fallow Land at Pusa, 1910.

(*Expressed as pounds of Nitrogen per acre—½ foot.*)

Depth.	4-4-10.	5-5-10.	25-5-10.	18-6-10.	24-6-10.	21-7-10.	10-8-10.	25-8-10.	13-9-10.	29-9-10	25-10-10.	Rainfall of the several periods.	
0″— 6″ ..	·90	2·75	1·20	3·30	·49	·87	·88	..	·64	2·31	1·39	April 4th to May 5th	·14″
6″—1′ 0″ ..	·71	·45	·66	18·31	12·80	1·46	·72	·61	·56	1·33	1·90	May 6th to May 25th	·25″
1′ 0″—1′ 6″ ..	·63	·45	·45	·73	6·30	12·00	·73	1·87	1·49	1·67	1·77	May 26th to June 17th	3·71″
1′ 6″—2′ 0″ ..	·94	·46	·36	·40	·95	13·97	1·34	1·20	1·63	1·75	1·35	June 18th to June 24th	3·36″
2′ 0″—2′ 6″ ..	·65	·46	·33	·33	·48	1·17	2·42	2·70	·94	1·50	1·16	June 25th to July 21st	5·48″
2′ 6″—3′ 0″ ..	·80	·46	·36	·22	·45	·47	9·37	10·50	1·58	2·01	·98	July 22nd to Aug. 10th	4·39″
3′ 0″—3′ 6″ ..	·86	·60	·34	·33	·34	·53	5·75	22·90	2·75	3·97	1·72	Aug. 11th to Aug. 25th	6·57″
3′ 6″—4′ 0″ ..	·80	·42	·32	·33	·39	·41	1·30	3·33	3·20	9·34	2·56	Aug. 26th to Sept. 13th	1·97
4′ 0″—4′ 6″ ..	1·15	·63	·25	·31	·37	·34	·88	1·23	12·50	7·93	8·42	Sept. 14th to Sept. 29th	1·97″
4′ 6″—5′ 0″ ..	·59	·49	·36	·28	·51	·46	·90	·87	15·07	2·11	20·03	Sept. 30th to Oct. 25th	4·16″
5′ 0″—5′ 6″ ..	·90	·51	·44	·35	·44	·35	2·23	·65	2·50	1·28	5·44		
5′ 6″—6′ 0″ ..	·71	·53	·58	·34	·35	·42	3·75	·54	1·76	·94	5·44		
6′ 0″—6′ 6″ ..	·63	·73	·81	·45	·52	·43	4·57	·60	1·27	1·22	1·73		
6′ 6″—7′ 0″ ..	·63	·92	·70	·72	·44	·55	·71	trace	·84	·73	1·71		
7′ 0″—7′ 6″ ..	·76	·99	·66	·80	·29	trace	·63	..	·94	·63	1·09		
7′ 6″—8′ 0″ ..	·35	·97	·67	·94	trace	..	·59	..	·99	·99	1·27		
8′ 0″—8′ 6″ ..	·34	1·24	1·01	3·90	..	·57	·58	..	·90	1·06	1·04		
8′ 6″—9′ 0″ ..	..	·94	1·12	4·29	trace	..	·60	..	·89	·68	1·26		

1909 was so liberal that, as has been sufficiently explained, the nitrate was removed as though it had mostly existed at the end of the hot weather in the 2nd and 3rd feet or so of soil of each gauge. It is of course out of the question to take soil samples from the gauges, at least if this were done, they would probably be ruined. But in order to try to obtain evidence on the subject a record was kept in some neighbouring land during 1910. The land in question is situated close to the gauges—a few yards to the East. It had had grass on it until October 1908 when this was removed. Since then it has been kept lightly cultivated and free from weeds. It is an open question whether one should expect nitrification to be as active in this soil in 1910 as it was on the gauges. The soil of the latter contained no nitrate whilst grass grew upon it (see page 68). Thereafter nitrification was active and nitrate equal to 20lbs. from gauge I and 18lbs. from gauge III was washed out in 1907, that is during the second monsoon after clearing the grass off them. This period (1907) would correspond for the fallow land which we are considering with the monsoon of 1910. The fallow land had of course been subject to the very heavy continuous rains of 1909 and since the drainage of that year must have passed to a depth of some 12ft. from the surface, the nitrate which had been formed in this land during 1909 would have been washed below about 8ft. from the surface.

The details of the nitrate record in this soil during 1910 are set out in Statement No. VIII, but before examining them attention may be directed to the information contained in Statement No. VII which refers to the amount of nitrate present in some contiguous plots of land shortly after harvest. It is evident from the data in Statement VII that no appreciable nitrate was present in the upper 5ft. immediately after harvesting the wheat, but that 28 days after harvesting the linseed and 35 days after harvesting the mustard, small quantities of nitrate were found here and there. Below 6ft. small quantities were found almost uniformly in all cases.

Returning now to Statement No. VIII it is to be explained that the quantities are expressed as pounds of nitric nitrogen per acre for

each 6″ stratum of soil. Thus the first quantity is ·90lbs. N. in the topmost 6″ of soil on April 4th. This means that the sample contained nitrate equal to this quantity of nitrogen in $\frac{43560}{2}$ c. ft. The next 6″ of soil contained ·71lbs., so that the first foot was estimated to contain 1·61lbs.; the first 3ft. contained 4·63lbs.; the top 6ft. of land contained 9·68lbs. per acre. The samples were taken in 2″ diameter soil borings, and the nitrate determined by the phenol-disulphonate method as described on page 66. Succeeding borings were taken at distances of about 3ft. from one another. But since the estimate is based on these small soil columns, and since it is not to be expected that nitrification is equally active in different places in a field, even though they are closely contiguous, too rigid a comparison is not admissible between these several tests. For example on April 4th the soil between 4′ and 4′6″ contained 1·15lbs.; on May 5th the corresponding soil only a few feet distant contained only ·63lbs. During the interval the rainfall was only ·14″. There would of course be some movement of water towards the surface during the month, but such movement is so slow that diffusion would equalise to some extent any movement of salts on that account; moreover any upward movement should have tended to increase the concentration of nitrate in the stratum 3′ 6″ to 4′ 0″ which was not found to be the case. The differences found in the several samples are simply due to the fact that nitrification is more active in one place than in another. Hence in drawing conclusions from these data only broad issues are admissible.

The first point to notice is the very uniform quantity of nitrate throughout the soil in April. This was not particularly surprising, because on the one hand the previous rains must have removed the nitrate which was then present to at any rate 8ft. from the surface, whilst on the other hand the temperature of the cold weather is fairly low and the hot weather had only just set in. From this point of view any large amount of nitrification was, therefore, not looked for. At the same time, it is, I think, generally assumed that nitrification in fertile soils continues throughout warm weather, and on this account formation of nitrate might have been anticipated in the first

3ft. of soil during, say, the preceding October. Any such nitrate must have remained *in situ* because there had been no drainage subsequently. However, there is no evidence of any marked formation of nitrate in the upper 3ft. at that time. Then follow two tests in May. The temperature of the upper soil at this period may be stated thus ; the figures being averages for a few days near the hottest period :—

	Maximum. °C.
3″	36·9
6″	34·1
9″	33·0
12″	32·3
18″	31·3
24″	30·8

The soil above 3″ may become too hot for nitrification, but our records do not indicate that it rises in the soil below 3″ at any period so high as to affect this process. At this period there was some nitrate formed ; the test of May 5th showed an increase of about 2lbs. in the top 6″, that of 25th about 1lb.

RAINFALL.

Date.	Inches.
June 15th	·19
June 16th	2·15
June 17th	·29
June 18th	·94
June 19th	·05
June 20th	·02
June 23rd	2·35

After the first heavy rain of June, which is marginally stated for easy reference, a definite and large increase in the amount of nitrate took place. It is seen in the test of June 18th when a marked increase was found to have occurred in the second 6″ of soil.

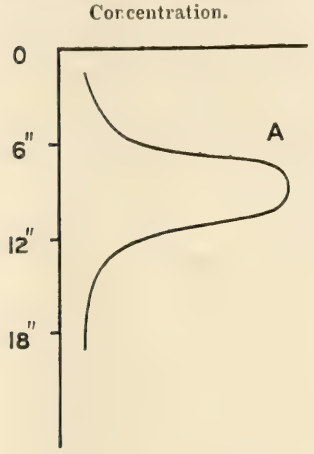
Following the course of events it is seen from Statement No. VIII that the position of the nitrate was very well defined, and that as the monsoon continued the position of maximum concentration of nitrate was further and further removed from the surface,—a result which in some respects would be anticipated.

Then considering next the quantities of nitrate, these will be most conveniently expressed as pounds of nitric nitrogen *in excess* of the hot weather quantity, and these are stated marginally. There was evidently a general increase in

June 18th	19 lbs.
June 21th	18 lbs.
July 21st	25 lbs.
August 10th	16 lbs.
August 25th	38 lbs.
September 13th	37 lbs.
September 29th	29 lbs.
October 25th	50 lbs.

this quantity, although individual tests, such as August 10th and September 29th, showed decreases.

The next point to consider is the probable stratum in which the nitrate was formed. It is evident that the nitrate of June 18th may be represented by the curve in the marginal chart, and the question is, was this band of nitrate formed in the first 6″ and then washed downwards principally by the rain (2·1″) of June 16th, or was it formed more nearly in the second 6″? The 2″ of rain would have been, perhaps, just sufficient to displace this nitrate through 6″ of soil, though there is a doubt about this. The question of the uniformity of drainage is discussed subsequently, but it seems impossible to form a *definite* conclusion as to whether this nitrate was formed principally in the first 6″ of soil and then washed downwards, or whether it was principally formed in the second 6″ of soil.

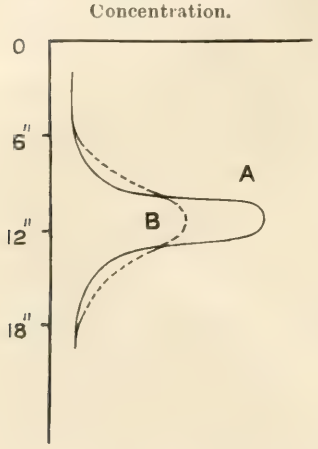


There is however the following line of argument which seems sound. Since no increase of nitrate was definitely met with until after the rain of June 16th * it is a reasonable assumption that nitrification only became active *after* this fall of rain. If now the process were an exceedingly rapid one, it would be just as probable that the nitrate was formed principally in the top 6″ and then washed down, as that it was formed in the second 6″ and remained practically *in situ*. But such processes as nitrification are usually not rapid, and this being the case, it would follow that the nitrate would form *after* the rain-water had reached a certain stratum ; thus, with reference to any such stratum as the top 6″ of soil, had this been the principal seat of nitrification the water would have passed below into the next 6″ before the nitrate had formed and the nitrate would then have been found in the

* This circumstance has recurred this year, 1911.

top 6″ on June 18th ; on the other hand, since the amount of water, 2·15″, was insufficient under the then soil-moisture conditions to pass below 12″ in any material degree, if the nitrate were principally formed in the second 6″ it would remain there and be met with in the test of June 18th, which was what was actually experienced. Thus, arguing in this way, the inference is that the nitrate was principally formed in the second 6″ of soil.

The next test showed 12lbs. nitrate in the second 6″ and 6lbs. in the third 6″. This could be accounted for as indicated by the marginal chart, curve A, that is a simple displacement of the nitrate through about 3″ of soil, or, as is more probable, there was some slight *dilution* of the nitrate solution by the descending water in which case the dotted curve B would more nearly indicate the state. By July 21st the nitrate had moved downwards 6″ and had at the same time increased in quantity, whilst above it in the first foot no more nitrate was formed. It seems probable that the increased quantity was due to nitrate formation in the second foot. There is one factor in relation to this subject which is important. Suppose a quantity of nitrate q′ to be formed in a stratum A during the time period t′, and that subsequently during a second time interval t″ a further quantity q″ of nitrate is formed in the same stratum A ; then if (i) the water in A is stationary, the result will be an increased concentration of nitrate in A, whilst if (ii) there is a downward movement of water in progress as during wet weather, there cannot possibly be any increase in the concentration of nitrate in A. On the contrary, there will be a general tendency towards a decreased concentration. The very fact of the concentration of the nitrate of the Pusa soil remaining so high and approximately steady is a proof that either (i) the descending rain water simply displaced it downwards, or (ii) that the



effect of dilution was neutralised by nitrification occurring *in the same stratum* as the principal band of nitrate occupied. That some dilution occurs during wet weather seems certain, though the evidence considered in Part IV indicates that this would be small.

If the difference of concentration in succeeding 6″ strata of soil at each date of testing be considered, it is seen that this difference is less and less well marked, whilst concurrently there is no general decrease in the maximum concentration. Thus on June 18th the concentration is 18 in the stratum 6″ to 1′ 0″, whilst it is less than 1·0 in the stratum 1′ 6″ to 2′ 0″. Similarly abrupt differences existed in July. In August the difference was more gradual; the principal quantity of nitrate was situated at 2′ 6″ to 3′ 0″, in the next 6″ it was 6 and in the next lower 6″ of soil it was 1·0. Similarly *above* the stratum of maximum concentration, the differences of concentration had become less abrupt. Since the quantity of nitrate at the stratum of maximum concentration remained so high, one can only conclude that nitrate was being formed in the stratum of maximum concentration and also to a certain extent above and below it. Later, in September, nitrate seems to have been formed throughout a larger volume of soil. Certain it is that whilst nitrate was first formed very rapidly in the first foot of soil, there was practically no further nitrification in this stratum until September when small amounts were again formed. The observation agrees very well with that of C. A. Jensen(9) who concluded that nitrate is formed in successive soil strata, and not principally in the first foot (say) of soil. The explanation may be that ammonia formation ceased rapidly after the monsoon set in, thus limiting the amount of nitrite and nitrate; but whether the monsoon first accelerated and then retarded indirectly the one process or the other or all simultaneously, it seems certain that nitrate is only formed in any one place during a short period, and does not recur in it until after the lapse of considerable time. The current year's record 1911 substantiates that of 1910. The subject is rather

(9) Seasonal nitrification as influenced by crops and tillage, U. S. Dept. Agri., Bur. Plant Ind., Bull. 173.

a matter of speculation at present, because the evidence obtained by nitrate determinations in the field are admittedly accompanied by such errors that only probabilities are admissible. The behaviour of the drain-gauges, however, lends some support to the idea indirectly. If reference be made to the *details* of drainage from the gauges (Statements IX to XIV) for years of large rainfall when more water passed through 3 ft. gauges at Pusa or Cawnpore than was required to displace the whole water present at any one time—say 15″—it will be seen that the later drainage always contains much less nitrate than the early drainage, whereas if nitrification had been uniformly in progress during the monsoon this should not have been the case.

It remains to consider in how far the nitrate observations in the field agree with the course of events in the gauges. The data of Statement No. VIII show that the chief quantity of nitrate in the field passed below 3ft. from the surface at the end of August and that it descended into the 5th and 6th feet early in October (all heavy rain had ceased by October 5th). The nitrate commenced to come out of No. III gauge (3ft. deep) in August, but the major part of its nitrate came out with the drainage of early October, *i.e.*, if a strict comparison between the two cases be made, $4\frac{1}{2}$″ more drainage was required to bring out the nitrate from the gauge than to displace the major part of the nitrate below 3ft. in the field. In part this would be accounted for by the fact that the 3ft. gauge, being cut off from supplies of water from below, would dry out more perfectly during the dry season than the upper 3ft. in the field. On the assumption that the quantity of water lost during dry weather depends on the compound interest law and that hence $Q = be^{-at}$, I calculate the difference to have been approximately 1·8″, say 2″ since it is not possible to calculate it exactly. The difference between $4\frac{1}{2}$″ and 2″ would then represent the quantity of water which was "held up" by the false bottom. There is a general idea that because the soil of a drain-gauge rests on a false bottom, water will pass through it more readily than in the field. Such is not the case. On the contrary, the effect of the false bottom is rather to cause a certain amount of water

to be detained, in the same manner as the lower part of a capillary tube will retain a certain quantity of water, which latter would, if a second similar tube were brought into contact with this water in the first tube, cause the water to drain away into the added tube(10). The only further remark which is necessary is that since a rigid comparison between the two cases is not admissible, it would certainly be a mistake to state that $2\frac{1}{2}''$ of water was thus "held up;" it seems to me that this figure is probably a good deal too high, and that actually perhaps 1″ of water was thus detained by the false bottoms.

Eventually 36lbs. of N. was obtained from the 3ft. gauge in $6\frac{1}{2}''$ of drainage which is sufficient to saturate about $1\frac{1}{2}$ c.ft. of soil. In comparison with this the field soil contained some 41lbs. N. between 3ft. and 6ft. on October 25th. These quantities are similar and on this account strengthen the admissibility of comparing the gauge with the field, but it must at the same time be remembered that some part of the field-nitrate may have been formed below 3ft. from the surface.

In the second place, a comparison of the field with gauge No. 1 (6ft.) is of interest.

There was found in the field, 5·9lbs. N. in the sixth foot and 4·5lbs. in the 7th foot on August 10th, whilst the test of August 25th showed no such quantities. One can only conclude that material amounts of nitrate were formed in the lower soil at this period of the season, though not so uniformly as in the upper soil. From the gauge 7·7lbs. N. was obtained in August. Thus in so far as quantities of N. are concerned the circumstances agree very well. But what is not so clear is an answer to the question ,' why did nitrification become active in these lower strata at so late a period ?' In the upper soil the low proportion of soil moisture during the hot weather might be suggested as one of the controlling factors, but this would hardly apply to the sixth and seventh feet of soil where the moisture in fallow land does not fall during the dry season below about 16 per cent. in comparison with 24 per cent. for the wet season.

(10) See also Book of the Rothamsted Experiments, p. 22.

PART IV.

The nature of water movements during wet weather.—In the foregoing paragraphs the principal facts relating to the Indian drain-gauge records have been set out, but there remains one important matter to be considered. When rain falls the term "drainage" is applied to the descending water. In what manner does this water flow through the soil?

Probably the most definite pronouncement on this subject is that of Lawes, Gilbert and Warington(11) in their very exhaustive paper that on the drainage data obtained at Rothamsted.

"It would be a mistake to regard an ordinary soil as a uniform porous mass, which simply becomes saturated with water, and then parts with its surplus by drainage; soil is, in fact, penetrated by innumerable small channels, and through these more or less of the drainage always takes place. Some of these channels consist of surface-cracks, which becoming partly filled with sand and small stones, remain partially open after dry weather has ceased. The deeper channels are, however, not of this character, but are produced by the roots of plants, or to a still greater extent by the burrowing of worms. The soil drain-gauges we are now concerned with have furnished illustrations of both these actions. During the digging of the trenches round the gauges, barley-roots were observed penetrating the soil to a depth of 50 or 60 inches. When such roots decay, a small open channel is left through which drainage can take place. The burrowing of worms in the soil of the drain-gauges has proved a source of trouble in the collection of pure drainage-waters. Worms have not unfrequently appeared on the collecting funnel of the 20-inch gauge, having come through the soil above, and what appear to be worm-casts, dropped from the holes of the perforated iron plates, are of still more frequent occurrence. Worms have also appeared, though much more rarely, on the collecting funnels of the 40 and 60-inch gauges. The holes made by worms thus descend to a considerable depth, and if sufficiently numerous, must have an important influence on drainage.

"The drainage-water from a soil may thus be of two kinds: it may consist (1) of rain-water which has passed, with but little alteration in composition, down the open channels of the soil; or (2) of the water discharged from the pores of a satu-

(11) The Amount & Composition of the Rain & Drainage Waters collected at Rothamsted by Lawes, Gilbert & Warington, J. R. A. S. E., XXVII, 1881, p. 275.

rated soil. This latter water, the true drainage of the soil, will itself escape to a greater or less extent through the channels already mentioned. The respective proportions of *direct* and *general* drainage will vary much in different soils, and under different circumstances. In a light soil, of naturally free drainage, channels can play but an insignificant part, the rain being at once absorbed by the main body of the soil, and freely discharged again from its pores when saturated. In heavy soils, on the other hand, both the absorption and the discharge of water can take place but slowly, and the part which natural channels play in freeing the soil of water is more considerable. In a heavy soil direct channel-drainage will in most cases precede general drainage, a portion of the water escaping by the open channels before the body of the soil has become saturated: this will especially be the case if the rain fall rapidly, and water accumulates on the surface. When the soil is saturated, general drainage will become active. After rain has ceased, and the surface is free from standing water, the drainage which occurs will be entirely due to the general discharge from the saturated soil. The two kinds of drainage-water here mentioned differ much in composition, the direct channel-drainage containing a much smaller proportion of soluble salts than is found in the true discharge from the soil. This difference in composition has been very frequently exemplified in the analyses of the Rothamsted Drainage-waters, and has enabled us to trace the distinction between these two classes of drainage-waters."

That the upper soil frequently contains cracks, insect burrowings and other adventitious channels is of course a matter of common knowledge. The point of chief interest is however what proportion of the descending water passes by such adventitious channels? To what extent do they affect drainage? What proportion of an acre (say) is occupied by such channels? Judging by the amount of gas which bubbles out at the commencement of a heavy shower after dry weather, the water is soon stopped in its free passage: such channels must very rapidly close, in part by simply silting up, in part by the general swelling of the surrounding soil. The subject is of importance for this reason. Suppose the greater part of the descending water of wet weather passes chiefly through a small proportion of the passages in the soil, it is evident that it would only carry downwards with it that part of the soluble substances with which it came in contact. On the other hand, it is usually held that the water ascending during dry weather under the influence of surface tension moves very uniformly through the soil and this water must necessarily carry with it any soluble material. The nett result would then be a general concentration of soluble materials

very near the surface. It is true that such a concentration of salts is met with in certain countries, *e.g.*, the alkali lands of hot and dry countries, but these occur under very well defined conditions, and by far the greater part of the world's cultivated areas are free from any such indication that the movement of water during wet and dry weather, respectively, is such as that which has been suggested.

Lawes, Gilbert and Warington based their conclusion on the variation in composition of the drainage under varied conditions of rainfall; during heavy rain the concentration of the nitrate fell, and it rose again as drainage became less with the advent of fair weather. Reference will be made subsequently to this circumstance, but for the moment attention may be directed to the Rothamsted records of drainage. In the quoted paragraphs the fact of worm-casts being found to have come out from below the gauges is mentioned, this occurrence having been much more frequent from the 20″ than from the 60″ gauge. If then such cavities exert an important influence on the quantity of drainage, there should have been found more water percolating from the 20″ than from the 60″ gauge. Such however has not been the case; the amounts of water percolating have been remarkably equal. Speaking then from a broad stand-point, the more numerous worm burrowings which passed right through the Rothamsted 20″ gauge do not seem to have influenced the amount of drainage in any marked degree.

Leaving adventitious channels unnoticed for the moment, the most correct manner of viewing the downward passage of water through the soil is illustrated by the accompanying four small charts. In No. 1 the curve A illustrates the concentration of the water in the soil after a period of dry weather. With advent of rain, the uppermost soil becomes naturally wetted, that is, the water concentration is greater than lower down, as shown in chart II, curve B. The effect of this will be that water will move downwards by surface tension in precisely the same manner as it moves upwards during dry weather. Such movement will not be confined to large channels;

it will proceed throughout the whole mass of soil. Thus however much there may be a tendency, especially during heavy rain, for

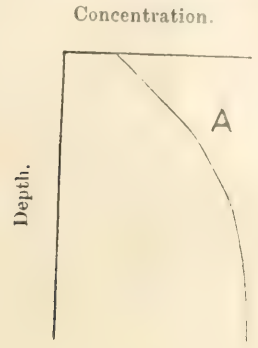


Fig. 1.

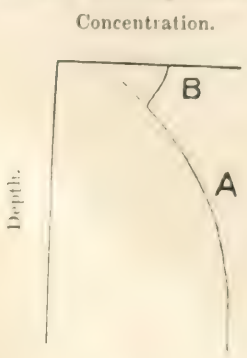


Fig. 2.

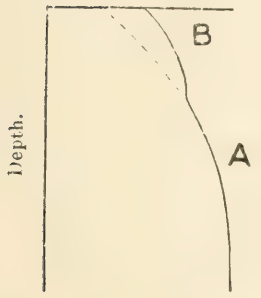


Fig. 3.

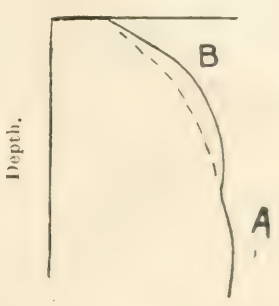


Fig. 4.

water to fully saturate the soil and descend by the action of gravity only, such movement must be invariably *preceded* (excepting in air-dry soil which is not here considered) by a movement of water throughout the soil mass under the influence of surface tension. Whether the subsequent course of events will be as indicated by charts III, IV depends on the character of the rainfall. If it has been an isolated 1″ or 2″ of rain followed by dry weather so as to admit of renewed evaporation at the surface, then these charts would indicate the subsequent changes of concentration : a " wave " of drainage would occur in the soil : the length of the " wave " could constantly increase, whilst its height would diminish. An example of such a wave has recently been quoted.(12) If, on the other hand, the

(12) Memoir, Dept. Agri. India, Chem. Series, Vol. I, No. 10, p. 266.

rainfall continued sufficiently, then the whole mass of soil would become supersaturated, and assuming the soil to be uniform, the concentration curve would naturally become a vertical straight line on the chart. These circumstances would, however, not affect the character of the movement of the most *advanced* portion of the "wave." Hall (13) too refers indirectly to this factor, he says :—"In relation to the drain-gauges . . . . . as communication between the subsoil and the soil of the gauges is cut off, all capillary movements of water both downwards during rain . . . . . are stopped at a certain point." That is, he recognises clearly that the water is carried downwards at least at certain times by surface tension.

Another feature related to this subject is referred to by Cameron in a recent paper(14) where he points out that, because soils contract as they dry and expand when wetted, and because it is "always either raining or not raining," therefore soil particles must be always in motion ; in fact the soil is not in a static but in a dynamic state. This view will probably receive very general acceptance and it is of great importance. It means that what is a comparatively large interval between two soil particles at one time, may become quite small at no distant interval of time.

Adding this to the former circumstances, it follows that the first descending water during wet weather will tend to flow very uniformly through the soil. The acceptance of these views would necessarily modify in a great measure that expressed by Lawes, Gilbert and Warington, in that whilst some water would unquestionably flow during heavy rain into adventitious channels, this can only occur in the top soil and would not materially affect the *uniformity* of the movements of descending water below a short distance from the surface.

In relation to the foregoing arguments both the drainage record of the monsoon of 1909 and the nitrate record in fallow land 1910, may be studied.

(13) The Book of the Rothamsted Experiments by A. D. Hall, p. 22.

(14) An introduction to the study of the soil solution by F. K. Cameron, J. Phys. Chem., XIV, p. 338.

Turning to the *drainage record*, and utilising firstly the data from gauge III (fallow—3ft.) we see from Statement No. XII that the first 9″ of drainage which came from the gauge in June contained nitrate equal to 145lbs. N. per acre. The concentration of nitrate in this drainage water varied from about 44 to 129 parts N. per million ; much of it approximated to 100 parts per million and the mean concentration was 69 parts. Passing to the second chief drainage period, 39lbs. N. was found in the 4·5″ of drainage between June 27th and July 20th. Subsequently the *concentration* of nitrate, as also the quantity of nitrate, was much less, *excepting* during periods of very slight drainage, that is, during fair weather, when the concentration always rose materially and sometimes approximated to as much as 300 parts.

The details of the first period agree well with what would occur if the movement of the water through the soil were extremely uniform. It is not to be supposed that the amount of nitrate formed is in all parts of a mass of soil and in the same stratum the same, so that variations of concentration are to be expected. On the other hand, it would be legitimate to raise the question whether since the nitrate is indirectly derived from organic matter and that organic matter formerly consisted, except in the topmost soil, of roots, it is chiefly formed in the immediate neighbourhood of such materials ? Further whether such situations are the "larger channels" through which the drainage-water has been held principally to flow ? Such a proposition would be just as well satisfied by the concentration of nitrate in the drainage water from No. III gauge as is the first proposition of uniform drainage ! Moreover the circumstance of an increased concentration during periods of little drainage, *i.e.*, when water is moving through the soil slowly, agrees with what would occur if the water flowed principally through large channels. At the same time, if this were the case, the concentration of nitrate on June 15th and again on June 29th should have been higher than they were. But if the rainfall and drainage are considered, the second proposition (flow through larger channels) receives but little support. The rainfall of the

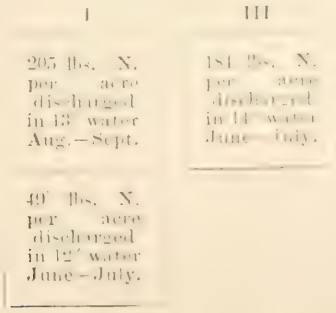
first period in June was 23″ (Statement No. XII) and the drainage 9″; evaporation was probably about 4″—5″ leaving some 8″ or 9″ to be absorbed by the soil, to replace that lost during the dry weather and which quantity coincides almost exactly with what is expected from our soil moisture records. Now one cannot very well argue at one and the same time a very uniform absorption of water by a partly dried soil mass, and a flow *chiefly* through comparatively few soil channels! The one seems to be a contradiction of the other. To a certain extent both phenomena could occur coincidently, but only to a limited one.

One factor which lends support to a very uniform distribution of nitrate in any one stratum of the soil is the concentration of the nitrate. Assuming that the flow of water is practically uniform through the soil, the concentration of nitrate in the soil-water will be the same as in the drainage water. Now calculation shows that even on the assumption of an uniform distribution, the concentration of nitrate in June was so high that it is difficult to account for the oxygen which is involved. But if it were argued that this nitrate is principally situated in a comparatively small number of passages, then it seems quite impossible to account for the oxygen. For example, supposing these "larger channels" were only one-tenth as numerous as the smaller ones, it would have to be assumed that the concentration of nitrate in these situations was something like ten times that which the *uniform* distribution would demand. Of course if this disproportion between "larger" and "smaller" channels were less, if for instance they were as 1 : 2, then the difficulty in accounting for the oxygen required would largely disappear, but obviously in that case so would the difference between "larger" and "smaller" channels!

Then, again, if the record from gauge No. I be brought into comparison with gauge No. III, it is seen that at the time when *its* chief amount of nitrate was washed out between August 3rd and September 14th (Statement No. XII) 204lbs. N. was contained in 12·7″ of drainage, or a mean concentration of 71 as against 69 for gauge No. III (*vide* supra). This alone indicates

a *uniform* movement of water. It is reasonable to assume that the amount of nitrate in the upper 3ft. of these two gauges corresponded approximately with one another. If now the descending water flows through a few larger channels, it must necessarily follow that the concentration of this solution would be affected, through the agency of diffusion, during its descent, by the solution in the other parts of the soil with which it would come in contact. Consequently the deeper such a solution passed, the more would its concentration tend to assimilate to that in the major part of the soil. But the drainage from No. I gauge in August to September which contained the greatest part of its nitrate, was very similar to that from gauge No. III in June to July. The quantity of nitrate as also its concentration were as nearly alike as could be expected, whereas if the movement of the water had not been uniform, the concentration of nitrate in the water from No. I gauge should have been decreased during its passage through the lower 3ft. of soil.

Again, if the quantities of drainage be correlated with the nitrate, further strong support is received to the idea of an uniform movement of water. The principal quantity of nitrate came out of gauge No. III quite at the commencement of the monsoon: that from No. I gauge commenced to come out after about 12″ of water had been discharged. Now the lower 3ft. of gauge No. I would contain during wet weather about 15″ of water. Thus if the movement of the water had been perfectly uniform throughout the soil mass, No. I should have discharged about 15″ before the nitrate of the upper 3ft. appeared. The case will be most graphically illustrated by the marginal woodcut.


I
III
205 lbs. N. per acre discharged in 13″ water Aug.—Sept.
184 lbs. N. per acre discharged in 14″ water June—July.
49 lbs. N. per acre discharged in 12″ water June—July.

The two quantities, 15″ and 12″ provide indeed the best index we have of the amount of irregularity in the movement of the descending water: on the basis of such an argument it may be said that the irregularity *in this soil* was such that the descending water passed down about $15x$″, whilst if the process had been perfectly uniform should have descended only $12x$.″

Whilst this evidence supports the idea of a very uniform movement of water through the soil, the circumstance of the very high concentration of nitrate in the drainage from No. III gauge during periods of dry weather when drainage had almost ceased, is not readily explained. For one thing it is an unusual occurrence and did not exhibit itself at Pusa in the drainage of No. I gauge 1909, nor at all in the drainage of 1910, nor in any year at Cawnpore.

The nitrate record in the fallow land which has already been considered also indicates a very uniform movement of water. Had this not been the case, the "band" of nitrate would not have continued so well defined throughout the season.

Conclusions.

(i) The amount of drainage and evaporation in India exhibit the same characteristics that have been met with at Rothamsted, namely, the quantity evaporating is nearly independent of the season, whilst the drainage varies with the rainfall.

(ii) One effect of a crop is to reduce the amount of water *evaporating from the surface soil*, and the Indian records have provided an estimate of this protective effect. A good crop, whilst itself transpiring large amounts of water, will reduce loss of moisture in this manner to two-thirds or one-half of what it would be from fallow land.

(iii) The amount of ammonia present in the drainage-water both from bare fallow, as also from cropped land, is as small as has been found at Rothamsted. The amount of nitrate has been in years of good rainfall much greater than at Rothamsted.

(iv) The amount of nitrate in drainage-water from cropped land is very much less than from fallow land, and there is some evidence that higher plants interfere with nitrification.

(v) Nitrification has been found at Pusa to be active only during wet weather and then only for a short time.

(vi) The evidence of the Indian records goes to show that the water descending during wet weather passes very uniformly through the soil and not chiefly by means of "larger channels" as has been commonly supposed.

STATEMENT No. IX (*a*).

Cawnpore drain-gauge data. 1904.

Period.			Rainfall inches.	Gauge No. I. 6ft. deep Fallow.			Gauge No. II. 6ft. deep Fallow.			Gauge No. III. 3ft. deep Fallow.			Gauge No. IV. 3ft. deep Fallow.		
				Drainage inches.	Nitrogen as nitrate.		Drainage inches.	Nitrogen as nitrate.		Drainage inches.	Nitrogen as nitrate.		Drainage inches.	Nitrogen as nitrate.	
					Parts per million.	lbs. per acre.		Parts per million.	lbs. per acre.		Parts per million.	lbs. per acre.		Parts per million.	lbs. per acre.
June	1—15	..	·26	..	..	..	No record.	..	..	..	..	..	No record.	..	..
	16—30	..	3·77	..	..	..		..	..	..	..	..		..	..
July	1—15	..	5·67	1·16	13·44	4·87		..	..	1·39	21·98	6·81		..	..
	16—31	..	11·13	2·86	27·82	18·05		..	..	3·78	23·54	20·19		..	..
Aug.	1—15	..	6·74	5·88	29·84	39·81		..	..	5·34	10·43	12·63		..	..
	16—31	..	4·79	4·04	24·20	22·19		..	..	3·81	7·58	6·56		..	
Septr.	1—15	..	10·77	5·45	14·32	17·72		..	..	6·49	5·96	8·78		..	..
	16—30	..	2·50	1·71	9·58	3·72		–	..	1·67	4·56	1·73		..	..
Octr.	1—15	..	*Nil.*	·10	3·92	·09		..	..	*Nil*	*Nil*	*Nil*		..	..
	16—31	..	·03	·02	3·12	·01				*Nil*	*Nil*	*Nil*		..	..

STATEMENT No. IX (*b*).

Cawnpore drain-gauge data, 1905.

Period.	Rainfall inches	Gauge No. I, 6ft. deep Fallow.			Gauge No. II, 6ft. deep Fallow.			Gauge No. III, 3ft. deep Fallow.			Gauge No. IV, 3ft. deep Fallow.		
		Drainage inches.	Nitrogen as nitrate.		Drainage inches.	Nitrogen as nitrate.		Drainage inches.	Nitrogen as nitrate.		Drainage inches.	Nitrogen as nitrate.	
			Parts per million.	lbs. per acre.		Parts per million.	lbs. per acre.		Parts per million.	lbs. per acre.		Parts per million.	lbs. per acre.
June 1—15 ..	*Nil*	..	..	..	No record.	..	..	..	..	..	..	..	..
16—30 ..	*Nil*	..	..	..		..	..	..	..	..	..	..	..
July 1—15 ..	5·62	..	..	..		..	..	..	..	..	·36	14·08	·18
16—31 ..	2·52	·56	8·60	1·09		..	..	·40	11·17	1·03	·54	17·61	2·16
Aug. 1—15 ..	·29	·06	5·37	·07		..	..	..	..	..	..	..	..
16—31 ..	1·34	·80	10·90	1·98		..	..	·90	22·91	4·68	1·38	29·51	9·26
Septr. 1—15 ..	4·20	1·44	11·03	3·60		..	..	1·61	33·08	12·10	1·58	33·49	12·02
16—30 ..	·10	·26	10·41	·62		..	..	·01	19·77	·04	·01	18·10	·04
Octr. 1—15 ..	*Nil*	·02	10·05	·04		..	..	..	..	..	..	..	..
16—31 ..	..	..	..	..		..	..	..	..	..	..	..	..

STATEMENT No. IX (*c*).

Cawnpore drain-gauge data, 1906.

Period.	Rainfall inches.	Gauge No. I. 6ft. deep Fallow.			Gauge No. II. 6ft. deep Fallow.			Gauge No. III, 3ft. deep Fallow.			Gauge No. IV. 3ft. deep Fallow.		
		Drainage inches.	Nitrogen as nitrate.		Drainage inches.	Nitrogen as nitrate		Drainage inches.	Nitrogen as nitrate.		Drainage inches.	Nitrogen as nitrate.	
			Parts per million.	lbs. per acre.		Parts per million.	lbs. per acre.		Parts per million.	lbs. per acre.		Parts per million.	lbs. per acre.
June 1—15 ..	*Nil*	..	..	..	..	..	..	..	..	..	..	..	..
16—30 ..	5·44	·02	7·16	·04	..	..	..	·14	3·19	·10	·31	33·09	2·29
July 1—15 .	6·21	5·38	54·79	66·92	2·93	61·72	41·01	5·50	18·98	23·70	6·02	39·94	54·59
16—31 ..	2·41	·25	19·39	1·11	·19	79·57	3·49	·01	7·09	·01	·01	8·00	·02
Aug. 1—15 ..	10·92	9·35	39·25	83·23	9·12	60·55	125·30	9·12	15·29	31·65	9·83	10·85	24·22
16—31 ..	·59	·40	27·36	2·40	·31	43·26	3·06	·02	6·93	·03	·02	5·59	·03
Septr. 1—15 ..	6·73	3·32	33·02	24·87	3·83	30·41	26·42	3·41	6·71	5·19	3·69	5·24	4·39
16—30 ..	1·94	·31	21·86	1·53	·27	15·99	·96	·04	6·31	·06	·05	5·33	·06
Octr. 1—15 ..	·14	·08	9·38	·17	·05	22·40	·23	..	..	..	·01	1·66	..
16—31 ..	*Nil*	·02	6·63	·04	·14	13·27	·04	..	..	..	..	..	..

STATEMENT NO. IX (*d*).

Cawnpore drain-gauge data, 1907.

Period.	Rainfall inches.	Gauge No. I, 6ft. deep Fallow.			Gauge No. II, 6ft. deep Fallow.			Gauge No. III. 3ft. deep Fallow.			Gauge No. IV, 3ft. deep Fallow.		
		Drainage inches.	Nitrogen as nitrate		Drainage inches.	Nitrogen as nitrate.		Drainage inches.	Nitrogen as nitrate.		Drainage inches.	Nitrogen as nitrate.	
			Parts per million.	lbs. per acre.		Parts per million.	lbs. per acre.		Parts per million.	lbs. per acre.		Parts per million.	lbs. per acre.
June 1—15 ..	*Nil*	..	..	..	..	..	..	..	..	..	..	..	..
16—30 ..	·18	..	..	..	..	..	..	..	..	..	..	..	..
July 1—15 ..	·36	..	..	..	..	..	..	..	..	..	..	..	..
16—31 ..	7·07	..	..	..	..	..	..	·10	12·5	·29	·48	16·5	1·64
Aug. 1—15 ..	7·28	3·38	11·7	8·94	1·58	12·6	13·11	5·82	24·5	32·2	6·27	25·4	35·30
16—31 ..	2·09	·21	12·9	·61	·22	12·7	·62	..	..	..	·03	26·1	·20
Septr. 1—15 ..	*Nil*	·04	10·5	·08	·03	11·9	·10	..	..	..	·01	2·7	·01
16—30 ..	·17	·02	3·6	·02	·01	1·6	..	..	..	..	..	..	..
Octr. 1—15 ..	*Nil*	..	..	..	..	..	..	..	..	..	..	..	..
16—31 ..	*Nil*	..	..	..	..	..	..	..	..	..	..	..	..

STATEMENT No. IX (*e*).

Cawnpore drain-gauge data, 1908.

Period.	Rainfall inches.	Gauge No. I. 6ft. deep Fallow.			Gauge No. II. 6ft. deep Fallow.			Gauge No. III. 3ft. deep Fallow.			Gauge No. IV, 3ft. deep Fallow.		
		Drainage inches.	Nitrogen as nitrate.		Drainage inches.	Nitrogen as nitrate.		Drainage inches.	Nitrogen as nitrate.		Drainage inches.	Nitrogen as nitrate.	
			Parts per million.	lbs. per acre.		Parts per million.	lbs. per acre.		Parts per million.	lbs. per acre.		Parts per million.	lbs. per acre.
June 1—15 ..	*Nil*	..	..	..	..	..	..	..	..	..	..	..	..
16—30 ..	·19	..	..	..	..	..	..	..	..	..	..	..	..
July 1—15 ..	9·39	..	..	..	..	..	..	·17	30·89	1·16	·71	24·98	4·00
16—31 ..	3·39	1·78	23·43	9·49	1·87	36·78	15·62	2·07	31·43	14·76	1·95	33·87	15·01
Aug. 1—15 ..	5·32	2·34	28·09	14·92	2·28	31·52	15·97	2·62	35·22	21·28	2·83	23·82	15·29
16—31 ..	10·78	7·99	34·87	63·26	7·81	33·91	60·11	8·64	12·84	25·18	8·77	10·54	21·00
Septr. 1—15 ..	2·42	2·38	26·73	14·44	2·40	26·32	14·34	2·11	4·83	2·32	1·92	4·42	1·93
16—30 ..	*Nil*	·07	16·43	·27	·05	23·91	·25	*Nil*	..	..	*Nil*	..	..
Octr. 1—15 ..	·04	..	..	..	..	..	..	..	..	..	..	..	..
16—31 ..	*Nil*	..	..	..	..	..	..	..	..	..	..	..	..

STATEMENT No. IX (*f*).

Cawnpore drain-gauge data, 1909.

Period.	Rainfall inches.	Gauge No. I. 6ft. deep Juar.			Gauge No. II. 6ft. deep Fallow.			Gauge No. III. 3ft. deep Fallow.			Gauge No. IV. 3ft deep Juar.		
		Drainage inches.	Nitrogen as nitrate.		Drainage inches.	Nitrogen as nitrate.		Drainage inches.	Nitrogen as nitrate.		Drainage inches.	Nitrogen as nitrate.	
			Parts per million.	lbs. per acre.		Parts per million.	lbs. per acre.		Parts per million.	lbs. per acre.		Parts per million.	lbs. per acre.
June 1—15 ..	2·56	..	..	..	..	..	..	..	..	..	..	..	..
16—30 ..	3·13	..	..	..	..	..	..	..	..	..	..	..	..
July 1—15 ..	8·02	4·16	9·68	9·14	5·40	15·97	19·57	4·71	23·42	25·63	4·93	19·71	22·08
16—31 ..	11·15	7·50	10·54	17·94	8·13	17·39	32·08	8·97	9·46	19·27	8·68	1·13	2·21
Aug. 1—15 ..	1·91	·44	1·58	·16	·84	17·83	3·42	·58	·60	·08	·55	2·98	·38
16—31 ..	1·74	·99	*Nil*	*Nil*	·12	16·67	·47	2·21	3·14	1·57	*Nil*	*Nil*	*Nil*
Septr. 1—15 ..	4·00				1·95	13·99	6·20				1·99	·40	·18
16—30 ..	1·44	·07	·86	·01	·03	14·53	·11	*Nil*	..	..	*Nil*	..	..
Octr. 1—15 ..	*Nil*	..	..	..	..	..	..	..	..	..	..	..	..
16—31 ..	*Nil*	..	..	..	..	..	..	..	..	..	..	..	..

STATEMENT No. IX (*g*).

Cawnpore drain-gauge data 1910.

Period.	Rainfall inches.	Gauge No. I, 6ft. deep Maize.			Gauge No. II, 6ft. deep Fallow.			Gauge No. III, 3ft. deep Fallow.			Gauge No. IV, 3ft. deep Maize.		
		Drainage inches.	Nitrogen as nitrate.		Drainage inches	Nitrogen as nitrate.		Drainage inches.	Nitrogen as nitrate.		Drainage inches.	Nitrogen as nitrate.	
			Parts per million.	lbs. per acre.		Parts per million.	lbs. per acre.		Parts per million.	lbs. per acre.		Parts per million.	lbs. per acre.
June 1—15 ..	·45	..	..	..	..	..	..	..	..	..	..	..	..
16—30 ..	1·18	..	..	..	..	..	..	..	..	..	..	..	..
July 1—15 ..	1·14	..	..	..	..	..	..	..	..	..	..	..	..
16—31 ..	2·55	..	..	..	..	..	..	..	..	..	..	..	..
Aug. 1—15 ..	7·06	·04	4·27	·04	1·56	14·94	5·30	2·01	20·07	9·16	·84	2·11	·40
16—31 ..	3·43	·46	1·68	·18	1·88	11·83	5·06	1·69	26·86	10·33	1·17	1·27	·34
Septr. 1—15 ..	6·04	3·26	1·21	·89	3·63	14·16	11·67	3·69	15·84	13·28	3·47	·19	·15
16—30 ..	1·27	·16	2·66	·10	·15	17·25	·59	*Nil*	..	..	*Nil*	..	..
Octr. 1—15 ..	2·51	·54	2·02	·25	·14	20·11	·63	·70	9·92	1·59	·75	·65	·11
16—31 ..	*Nil*	·07	2·68	·04	·01	17·72	·04	*Nil*	..	..	*Nil*	..	..

STATEMENT NO. X.

Details of Drainage at Pusa, September 1907.

Date.		Rainfall, inches.	Gauge No. I. 6ft. deep—Bare fallow.			Gauge No. II. 6ft. deep—Cropped land.			Gauge No. III. 3ft. deep—Bare fallow.			Gauge No. IV. 3ft. deep—Cropped land.		
			Drainage, inches.	Nitric Nitrogen.		Drainage, inches.	Nitric Nitrogen.		Drainage, inches.	Nitric Nitrogen.		Drainage, inches.	Nitric Nitrogen.	
				Pts. per million.	Lbs. per acre.		Pts. per million.	Lbs. per acre.		Pts. per million.	Lbs. per acre.		Pts. per million.	Lbs. per acre.
September	1	7·37	·710	13·50	2·180	·279	·102	·0065	4·395	4·83	4·390	2·906	·086	·0567
,,	2	·71	1·642	11·00	4·080	·051	·078	·0009	·749	9·78	1·660	1·313	·063	·0189
,,	3	·29	·603	10·46	1·430	·188	·067	·0028	·197	14·70	·660	·242	·056	·0031
,,	4	1·96	·773	9·73	2·570	·773	·033	·0058	1·543	11·75	4·110	1·712	·123	·0478
,,	5	·31	·694	9·16	1·440	·695	·033	·0053	·335	20·36	1·550	·496	·056	·0063
,,	6	·67	·407	9·56	·880	·351	·045	·0036	·326	16·31	1·210	·207	·078	·0037
,,	7	·04	·431	9·84	·960	·437	·045	·0044	·259	23·51	1·390	·528	·056	·0067
,,	8	·02	·233	9·05	·480	·209	·033	·0016	·027	26·32	·160	·128	·101	·0029
,,	9	..	·125	9·67	2·730	·088	·045	·0009	·001	45·67	·012	·007	·579	·0009
,,	10	·60	·152	10·52	·360	·164	·045	·0017	·246	16·05	·890	·324	·055	·0041
,,	11	·11	·179	9·90	·400	·181	·045	·0018	·022	31·27	·160	·142	·067	·0022
,,	12	..	·083	7·37	·140	·068	·056	·0008	·002	49·05	·210	·008	·416	·0073
,,	13	..	..	·023	9·56	·050	·010	·101	·0002	·0003	26·10	·002	..	..
,,	14	..	..	·003	7·36	·005	..	..	..	·0003	100·00	·007	..	..
,,	15	..	..	·0006	8·28	·001	..	..	..	·0003	133·20	·009	..	..
,,	16	..	..	·0005	8·77	·001	..	..	..	·0003	182·60	·012	..	..
,,	17	..	..	·0004	6·33	·0006	..	..	..	·0002	144·00	·006	..	..
,,	18	..	1·09	·029	8·48	·056	..	..	..	·199	6·24	·282	..	..
,,	19	..	..	·088	8·66	·173	·137	·124	·0038	·003	25·42	·018	·004	·725	·0007
,,	20	..	..	·039	8·43	·075	·075	·078	·0013	·0003	60·30	·005	..	..	..
,,	21	..	·01	·003	8·10	·006	·006	·478	·0006	·0003	119·70	·010	..	..	..
,,	22	..	·45	·001	4·50	·001	..	..	..	·033	15·18	·114	..	..	..
,,	23	..	1·14	·228	9·16	·473	·433	·045	·0044	·405	1·80	·165	·859	·045	·0087
,,	24	..	·03	·361	9·84	·805	·344	·045	·0035	·028	23·40	·149	·183	·056	·0023
,,	25	..	..	·177	10·29	·414	·140	·045	·0014	·001	58·90	·013	·018	·315	·0013
,,	26	..	..	·067	8·71	·133	·039	·056	·0005	·0003	109·80	·007	..	..	..
,,	27	..	..	·012	8·77	·024	·004	·343	·0028	·0002	172·80	·009	..	..	..
,,	28	..	..	·001	10·68	·004	..	..	..	·0002	170·10	·009	..	..	..

STATEMENT NO. XI (*a*).

Details of Drainage at Pusa, June 1909.

Date.	Rainfall, inches.	Gauge No. I. 6ft. deep—Bare fallow.			Gauge No. II. 6ft. deep—Cropped land			Gauge No. III 3ft. deep—Bare fallow.			Gauge No. IV. 3ft. deep—Cropped land.		
		Drainage, inches.	Nitric Nitrogen.		Drainage, inches.	Nitric Nitrogen.		Drainage, inches.	Nitric Nitrogen.		Drainage, inches.	Nitric Nitrogen.	
			Pts. per million.	Lbs. per acre.		Pts. per million.	Lbs. per acre.		Pts. per million.	Lbs. per acre.		Pts. per million.	Lbs. per acre.
June 1	..	..	..	..	..	..	..	..	..	..	..	..	..
,, 2	·32	..	..	..	..	..	..	..	..	..	..	..	..
,, 3	·13	..	..	..	..	..	..	..	..	..	..	..	..
,, 4	..	..	..	..	..	..	..	..	..	..	..	..	..
,, 5	..	..	..	..	..	..	..	..	..	..	..	..	..
,, 6	·33	..	..	..	..	..	..	..	..	..	..	..	..
,, 7	1·55	..	..	..	..	..	..	..	..	..	..	..	..
,, 8	1·00	..	..	..	..	..	..	..	..	..	..	..	..
,, 9	3·55	..	..	..	..	..	..	..	..	..	..	..	..
,, 10	5·43	..	..	..	..	..	..	·162	14·85	·546	..	..	..
,, 11	·85	·131	15·75	·471	..	..	..	..	..	..	·499	11·70	1·325
,, 12	2·97	·639	15·30	2·219	1·014	·52	·120	1·616	14·85	5·448	1·339	18·00	5·471
,, 13	..	1·019	16·65	3·851	·001	1·53	..	·970	44·50	9·798	2·486	23·40	13·200
,, 14	·03	·291	19·35	1·278	·0002	..	..	1·816	95·40	39·330	·527	25·20	3·015
,, 15	·08	·141	18·90	·605	·0002	..	..	·151	129·60	4·443	047	26·10	·278
,, 16	2·09	·173	17·10	·671	·415	2·56	·241	·004	128·25	·116	·004	31·50	·029
,, 17	3·98	·821	16·87	3·144	1·365	2·56	·793	·786	81·00	14·450	1·297	19·80	5·830
,, 18	·37	1·087	15·27	3·768	·873	2·56	·507	·986	106·20	23·770	2·754	15·75	9·846
,, 19	·48	·805	16·87	3·083	·404	2·58	·237	1·827	76·50	31·730	1·377	9·90	3·095
,, 20	·04	·441	16·75	1·677	·264	2·02	·121	·878	72·00	14·350	·276	9·22	·578
,, 21	..	·211	15·07	·722	·114	1·80	·046	·083	70·87	1·335	·172	9·67	·378
,, 22	·11	·075	14·17	·241	·027	1·91	·012	..	..	..	·010	10·35	·023
,, 23	..	·026	14·85	·088	·002	3·65	·002	..	..	..	·001	12·60	·003
,, 24	..	·002	15·30	·007	·0005	2·92	..	..	..	..	·001	39·60	·009
,, 25	..	·0009	16·20	·003	·0004	2·47	..	..	..	..	..	..	..
,, 26	..	·0004	15·52	·001	..	..	..	..	..	..	..	..	..
,, 27	·68	·0003	16·42	·001	·019	3·04	·013	..	..	..	·0003	20·70	·001
,, 28	1·23	·011	11·81	029	·268	2·75	·167	..	..	..	·014	1·35	·004
,, 29	3·13	·250	15·75	·898	1·806	2·75	1·127	·688	54·00	8·434	2·810	4·95	3·158
,, 30	·61	·805	13·95	2·549	·646	2·47	·362	1·508	45·00	15·400	·748	4·95	·840

STATEMENT NO. XI (*b*).

Details of Drainage at Pusa, July 1909.

Date.	Rain-fall, inches.	Gauge No. I. 6ft. deep—Bare fallow.			Gauge No. II. 6ft. deep—Cropped land.			Gauge No. III, 3ft. deep—Bare fallow.			Gauge No. IV, 3ft. deep—Cropped land.		
		Drain-age, inches.	Nitric Nitrogen.		Drain-age, inches.	Nitric Nitrogen.		Drain-age, inches.	Nitric Nitrogen.		Drain-age, inches.	Nitric Nitrogen.	
			Pts. per million.	Lbs. per acre.		Pts. per million.	Lbs. per acre.		Pts. per million.	Lbs. per acre.		Pts. per million.	Lbs. per acre.
July 1 ..	·72	·623	16·65	2·355	·417	3·37	·319	·503	36·00	4·111	·259	3·82	·225
,, 2 ..	1·09	·655	16·31	2·425	·717	5·17	·841	1·152	30·37	7·942	1·099	4·27	1·055
,, 3 ..	·24	·743	16·20	2·732	·566	7·31	·939	·427	20·25	1·963	·355	4·27	·344
,, 4 ..	·17	·409	16·87	1·566	·300	9·22	·628	·115	20·25	·529	·189	4·50	·193
,, 5 ..	·38	·225	17·44	·891	·181	10·89	·447	·051	18·00	·208	·111	3·60	·091
,, 6 ..	..	·171	15·75	·486	·112	10·69	·272	·076	18·00	·310	.120	2·92	·079
,, 7 ..	..	·077	17·55	·307	·032	11·25	·082	·001	45·45	·010	·002	6·07	·003
,, 8 ..	..	·019	18·22	·079	.002	11·47	·052	·0008	77·40	·014	·001	5·85	·001
,, 9 ..	·36	·001	17·32	·004	·0007	11·25	·002	·0001	112·50	·003	·0006	6·75	·001
,, 10 ..	..	·0006	9·90	·001	·0004	10·80	·001	·0005	182·25	·021	·0004	9·67	·001
,, 11 ..	..	·0004	16·42	·001	·0004	11·70	·001	·0001	175·50	·004	·0004	6·75	..
,, 12 ..	..	·0002	16·20	..	·0003	11·25	·001	·0002	247·50	·011	·0004	11·25	·001
,, 13 ..	..	·0002	16·20	..	·0003	11·25	·001	·0001	234·00	·005	·0003	7·65	..
,, 14 ..	·66	·0001	13·50	..	·001	6·75	·002	·0003	276·75	·019	·0003	8·10	..
,, 15 ..	..	·0001	10·35	..	·0006	7·65	·001	·0003	200·25	·014	·0003	9·79	001
,, 16 ..	·18	·0001	14·40	..	·0008	8·10	·001	·0002	186·75	·008	·0003	8·77	·001
,, 17 ..	..	·0001	13·05	..	·0004	7·65	·001	·0002	184·50	·008	·0002	9·90	..
,, 18 ..	·27	·0001	13·05	..	·0003	7·65	..	·0001	200·25	·004	·0003	5·85	..
,, 19 ..	..	·0001	11·25	..	·0003	8·55	..	·0001	190·75	·004	·0002	9·00	.
,, 20 ..	..	·0001	12·65	..	·0003	9·00	..	·0001	234·00	·005	·0002	9·45	..
,, 21 ..	2·16	·0001	13·50	..	·119	9·20	·248	·0001	310·50	·006	·0001	6·30	..
,, 22 ..	1·72	·030	19·80	·135	·320	9·45	2·832	2·356	13·50	7·247	2·292	4·05	2·107
,, 23 ..	1·54	·548	20·25	2·519	·994	13·60	3·069	1·391	8·10	2·558	1·192	3·60	·974
,, 24 ..	..	·912	20·81	4·308	·497	13·50	1·523	·093	8·55	·180	·255	3·15	·182
,, 25 ..	·17	·514	24·97	2·914	·229	15·75	·819	·039	2·25	·020	·049	2·92	·032
,, 26 ..	·09	·257	25·65	1·496	·106	15·41	·371	·003	1·44	·001	·010	3·15	·007
,, 27 ..	·01	·116	28·12	·740	·032	15·75	·114	·0006	5·76	·001	·001	7·20	·002
,, 28 ..	..	·039	32·85	·291	·002	17·10	·008	·0003	124·87	·008	·0005	4·95	..
,, 29 ..	..	·004	26 77	·024	·0007	14·40	·002	.0005	95·62	·011	·0004	5·85	..
,, 30 ..	·32	·0007	31·95	·005	·0003	16·65	·001	·0001	122·62	·003	·0003	9·45	..
,, 31 ..	..	·0005	30·37	·003	·0003	16·65	·001	·0002	140·62	·006	·0003	7·65	..

STATEMENT NO. XI (*c*).

Details of Drainage at Pusa, August 1909.

Date.	Rainfall, inches.	Gauge No. I. 6ft. deep—Bare fallow.			Gauge No. II. 6ft. deep—Cropped land.			Gauge No. III. 3ft. deep—Bare fallow.			Gauge No. IV. 3 ft. deep—Cropped land.		
		Drainage, inches.	Nitric Nitrogen.		Drainage, inches.	Nitric Nitrogen.		Drainage, inches.	Nitric Nitrogen.		Drainage, inches.	Nitric Nitrogen.	
			Pts. per million.	Lbs. per acre.		Pts. per million.	Lbs. per acre.		Pts. per million.	Lbs. per acre.		Pts. per million.	Lbs. per acre.
August 1 ..	·18	·0003	27·90	·002	·0003	18·00	·001	·0001	150·75	·003	·0002	8·10	..
„ 2 ..	..	·0002	22·05	·001	·0003	13·50	·001	·0001	146·25	·003	·0002	5·62	..
„ 3 ..	1·70	·0001	19·80	..	·231	2·25	·118	·0001	209·15	·005	·032	1·80	·013
„ 4 ..	·08	·092	25·42	·531	·112	11·70	·297	·265	11·47	·690	·004	3·37	·003
„ 5 ..	·08	·321	24·97	1·819	·097	12·60	·277	·143	9·00	·292	·032	2·25	·016
„ 6 ..	1·64	·740	33·75	5·669	·626	11·25	1·599	1·261	6·75	1·932	1·190	1·35	·365
„ 7 ..	4·42	·807	38·25	7·007	2·009	8·55	3·899	1·113	6·30	1·592	2·209	1·12	·512
„ 8 ..	4·59	1·025	40·50	9·423	4·375	8·32	8·263	1·196	6·30	1·710	3·829	·90	·782
„ 9 ..	·53	1·190	54·90	14·830	·696	12·15	1·920	1·469	5·40	1·801	·399	·50	·056
„ 10 ..	·25	·845	81·00	15·540	·570	12·37	1·601	1·050	5·62	1·339	·495	·45	·051
„ 11 ..	·15	·387	87·70	7·705	·287	13·05	·850	·098	5·85	·130	·116	·60	·016
„ 12 ..	·33	·293	101·70	6·764	·251	13·50	·769	·265	6·07	·365	·216	·37	·018
„ 13 ..	·10	·195	99·90	4·422	·145	14·40	·474	·026	8·10	·048	·029	·63	·004
„ 14 ..	·04	·120	129·60	3·530	·078	13·72	·243	·021	8·10	·039	·016	·54	·002
„ 15 ..	..	·062	147·60	2·077	·021	16·87	·080	·002	10·80	·005	·003	·99	·001
„ 16 ..	·22	·020	140·40	·637	·002	19·12	·009	·0005	21·82	·002	·001	1·08	..
„ 17 ..	..	·014	142·20	·452	·0007	19·00	·003	·0004	55·80	·005	·0005	1·80	..
„ 18 ..	·38	·029	102·60	·675	·0005	18·90	·002	·053	8·10	·097	·0004	1·80	..
„ 19 ..	·17	·101	147·60	3·384	·032	14·40	·105	·061	5·40	·075	·0003	4·10	..
„ 20 ..	·02	·071	127·80	2·060	·020	14·40	·065	·006	7·65	·010	·0004	2·92	
„ 21 ..	·11	·015	147·60	·503	·001	18·90	·004	·001	10·12	·002	·0004	2·47	..
„ 22 ..	·05	·001	108·40	·025	·0005	13·95	·001	·0004	15·07	·001	·0003	2·25	..
„ 23 ..	..	·0007	135·00	·021	·0004	14·62	·001	·0002	21·60	·001	·0003	2·70	..
„ 24 ..	..	·0004	115·20	·010	·0003	19·80	·001	·0003	33·30	·002	·0003	2·70	..
„ 25 ..	2·08	·608	85·5	11·800	·594	9·00	1·214	1·078	6·07	1·485	1·103	·33	·083
„ 26 ..	1·39	·708	97·2	15·620	·739	8·32	1·396	1·089	6·30	1·557	1·022	·33	·076
„ 27 ..	·63	·672	108·0	16·480	·659	10·57	1·581	·731	6·75	1·120	·604	·45	·062
„ 28 ..	·08	·415	98·6	9·289	·324	12·15	·894	·124	7·20	·203	·183	·27	·011
„ 29 ..	·20	·227	102·6	5·287	·156	11·70	·414	·089	6·07	·123	·120	·27	·007
„ 30 ..	·60	·270	97·2	5·957	·231	11·25	·590	·395	6·07	·544	·347	·22	·017
„ 31 ..	4·09	·736	97·2	16·240	1·916	7·65	3·327	1·013	5·62	1·292	3·156	·22	·158

STATEMENT NO. XI (*d*).

Details of Drainage at Pusa, September 1909.

Date.	Rainfall, inches.	Gauge No. I. 6ft. deep—Bare fallow.			Gauge No. II. 6ft. deep—Cropped land.			Gauge No. III. 3ft. deep—Bare fallow.			Gauge No. IV. 3ft. deep—Cropped land.		
		Drainage, inches.	Nitric Nitrogen.		Drainage, inches.	Nitric Nitrogen.		Drainage, inches.	Nitric Nitrogen.		Drainage, inches.	Nitric Nitrogen.	
			Pts. per million.	Lbs. per acre.		Pts. per million.	Lbs. per acre.		Pts. per million.	Lbs. per acre.		Pts. per million.	Lbs. per acre.
September 1	..	2·112	54·00	25·890	1·203	9·22	2·518	1·749	5·17	2·053	·894	*Nil.*	..
,, 2	..	·526	55·80	6·663	·378	9·45	·811	·894	4·50	·913	·056	·22	·002
,, 3	..	·216	61·60	3·020	·145	11·47	·377	·024	*Nil*	..	·004	3·06	·003
,, 4	..	·083	57·60	1·085	·032	11·70	·085	·001	*Nil*	..	·001	1·46	..
,, 5	..	·023	58·95	·308	·002	13·50	·006	·0003	27·00	·002	·0006	1·57	..
,, 6	..	·002	55·80	·025	·001	11·47	·003	·0003	7·65	..	·0004	1·35	..
,, 7	..	·0008	54·00	·010	·0005	13·70	·001	·0002	45·00	·002	·0003	1·57	..
,, 8	..	·0003	55·80	·004	·0004	14·62	·001	·0002	37·80	·002	·0006	9·45	·001
,, 9	..	·0003	57·60	·004	·0004	17·10	·001	·0001	43·60	·001	·0003	1·80	..
,, 10	..	·0003	54·00	·004	·0003	20·70	·001	·0002	39·60	·002	·0003	2·25	..
,, 11	..	·0002	58·50	·002	·0003	24·30	·002	·0001	41·40	·001	·0002	2·02	..
,, 12	..	·0002	54·00	·002	·0003	25·20	·002	·0001	41·40	·001	·0002	2·25	..
,, 13	..	·0002	55·80	·002	·0002	31·05	·002	·0001	48·37	·001	·0002	1·80	..
,, 14	..	·0001	54·00	·001	·0002	32·85	·002	·0001	48·37	·001	·0002	2·47	..
,, 15	1·33	·0001	34·20	·001	·0002	35·55	·002	·0001	47·25	·001	·005	2·70	·003
,, 16	·09	·028	48·60	·309	·0002	28·80	·002	·0001	48·37	·001	·0005	2·47	..
,, 17	..	·038	52·20	·450	·0002	35·55	·002	·0001	65·25	·001	·0003	2·70	..
,, 18	..	·005	48·60	·055	·0002	31·60	·002	·0001	93·94	·002	·0002	2·92	..
,, 19	·30	0·009	46·80	·009	·0003	*Nil*	..	·0001	11·25	..	·0002	3·15	..
,, 20	..	·0004	40·50	·004	·0002	27·90	001	·0001	162·00	·004	·0002	3·37	..
,, 21	·46	·0004	35·10	·003	·0002	26·10	·001	·0001	132·75	·003	·0002	3·37	..
,, 22	..	·0002	36·90	·002	·0002	27·00	·001	·0001	135·00	·003	·0003	3·15	..
,, 23	..	·0002	44·10	·002	·0002	33·30	·002	·0001	130·50	·003	·0003	4·95	..
,, 24	·10	·0002	23·40	·001	·0002	33·75	·002	·00005	130·50	·001	·0002	4·27	..
,, 25	·61	·0001	39·60	·001	·0002	36·00	·002	·00005	171·00	·002	·003	2·92	·002
,, 26	·07	·002	32·40	·015	·0002	44·40	·002	·00005	200·25	·002	·0005	3·60	..
,, 27	·41	·032	38·47	·279	·003	25·20	·017	·00005	191·25	·002	·002	2·92	..
,, 28	..	·052	45·90	·542	·046	13·50	·144	·00005	292·50	·003	·0005	5·62	..
,, 29	..	·064	45·00	·623	·035	12·15	·097	·00005	355·5	·004	·0003	4·95	..
,, 30	1·13	·011	36·90	·092	·049	6·30	·070	·0001	76·5	·002	·331	·67	·050

STATEMENT NO. XI (*e*).

Details of Drainage at Pusa, October 1909.

Date.	Rain-fall, inches.	Gauge No. I. 6ft. deep—Bare fallow.			Gauge No. II. 6ft. deep—Cropped land.			Gauge No. III. 3ft. deep—Bare fallow.			Gauge No. IV. 3ft. deep—Cropped land.		
		Drain-age, inches.	Nitric Nitrogen.		Drain-age, inches.	Nitric Nitrogen.		Drain-age, inches.	Nitric Nitrogen.		Drain-age, inches.	Nitric Nitrogen.	
			Pts. per million.	Lbs. per acre.		Pts. per million.	Lbs. per acre.		Pts. per million.	Lbs. per acre.		Pts. per million.	Lbs. per acre.
October 1 ..	2·27	·392	32·40	2·883	·758	5·40	·929	2·200	2·70	1·348	1·916	·22	·096
„ 2 ..	·63	·965	34·20	7·492	1·421	4·95	1·597	·696	2·70	·427	1·081	·22	·054
„ 3 ..	..	·967	27·90	6·124	·458	5·40	·561	·014	8·55	·027	·157	·67	·024
„ 4 ..	..	·398	23·40	2·114	·203	5·40	·249	·001	23·85	·005	·020	·67	·003
„ 5 ..	..	·173	21·15	·831	·076	5·17	·089	·001	18·00	·004	·003	·90	..
„ 6 ..	..	·070	18·00	·286	·018	6·07	·025	·0002	63·00	·003	·001	·90	..
„ 7 ..	..	·018	19·35	·079	·002	6·30	·003	·0001	58·50	·001	·0004	1·57	..
„ 8 ..	..	·002	16·65	·008	·001	29·25	·007	..	*Nil*	..	·0003	1·80	..
9 ..	..	·001	16·65	·004	..	..	..	..	..	..	..	..	..

STATEMENT NO. XII.

Drainage at Pusa, 1909. *Totals for six periods.*

Period.	Rainfall, inches.	Gauge No. I.		Gauge No. II.		Gauge No. III.		Gauge No. IV.	
		Drainage, inches.	Nitrogen, lbs. per acre.	Drainage, inches.	Nitrogen, lbs. per acre.	Drainage, inches.	Nitrogen, lbs. per acre.	Drainage, inches.	Nitrogen, lbs. per acre.
June 16-26	22·86	5·863	21·829	4·484	2·079	9·279	145·316	10·790	43·070
June 27 / July 20	9·72	3·991	14·324	5·072	5·260	4·524	59·027	5·712	6·009
July 21 / August 2	6·19	2·422	12·438	3·301	8·990	3·884	10·047	3·801	3·304
August 3 / „ 24	14·86	6·329	87·084	9·555	20·581	7·032	10·143	8·574	1·839
August 25 / September 14 ..	9·07	6·400	117·693	6·383	13·228	7·189	9·303	7·487	·420
September 15 / October 9 ..	7·40	3·217	22·109	3·072	3·804	2·916	1·853	3·522	·233
		28·222	275·477	31·867	53·942	34·824	215·589	39·886	54·875

STATEMENT NO. XIII (*a*).

Details of Drainage at Pusa, June 1910.

Date.	Rainfall, inches.	GAUGE NO. I.					GAUGE NO. II.	GAUGE NO. III.					GAUGE NO. IV.				
		Drainage, inches	Nitrogen in Drainage water.					Drainage, inches.	Nitrogen in Drainage water.				Drainage, inches.	Nitrogen in Drainage water.			
			As ammonia.		As nitrate.				As ammonia.		As nitrate.			As ammonia.		As nitrate.	
			Pts. per million.	Lbs. per acre.	Pts. per million.	Lbs. per acre.			Pts. per million.	Lbs. per acre.	Pts. per million.	Lbs. per acre.		Pts. per million.	Lbs. per acre.	Pts. per million.	Lbs. per acre.
June 1	·78						No Drainage.										
,, 2	..																
,, 3	...																
,, 4	·09																
,, 5	...																
,, 6	..																
,, 7	·05																
,, 8	...																
,, 9	...																
,, 10	.																
,, 11	...																
,, 12	..																
,, 13	...																
,, 14	·01																
,, 15	·19																
,, 16	2·15																
,, 17	·29	..	...	...	...	..	...	..	...	...	..	..	·0139	·200	·0006	1·80	·06
,, 18	·94																
,, 19	·05																
,, 20	·02																
,, 21																	
,, 22	.																
,, 23	2·35	..	..		.	...	.	.	...	...	...	...	·1286	·383	·0111	·90	·026
,, 24																	
,, 25	...																
,, 26																	
,, 27	·32																
,, 28	·02																
,, 29	·20																
,, 30	.																

STATEMENT NO. XIII (*b*).

Details of Drainage at Pusa, July 1910.

Date.	Rainfall, inches.	GAUGE NO. I. Drainage, inches.	GAUGE NO. I. Nitrogen in Drainage water. As ammonia. Pts. per million.	GAUGE NO. I. Nitrogen in Drainage water. As ammonia. Lbs. per acre.	GAUGE NO. I. Nitrogen in Drainage water. As nitrate. Pts. per million.	GAUGE NO. I. Nitrogen in Drainage water. As nitrate. Lbs. per acre.	GAUGE NO II.	GAUGE NO. III. Drainage, inches.	GAUGE NO. III. Nitrogen in Drainage water. As ammonia. Pts. per million.	GAUGE NO. III. Nitrogen in Drainage water. As ammonia. Lbs. per acre.	GAUGE NO. III. Nitrogen in Drainage water. As nitrate. Pts. per million.	GAUGE NO. III. Nitrogen in Drainage water. As nitrate. Lbs. per acre.	GAUGE NO. IV. Drainage, inches.	GAUGE NO. IV. Nitrogen in Drainage water. As ammonia. Pts. per million.	GAUGE NO. IV. Nitrogen in Drainage water. As ammonia. Lbs. per acre.	GAUGE NO. IV. Nitrogen in Drainage water. As nitrate. Pts. per million.	GAUGE NO. IV. Nitrogen in Drainage water. As nitrate. Lbs. per acre.
July 1	1·02												·0272	·130	·0008	1·35	·008
,, 2	·03																
,, 3																	
,, 4	·19																
,, 5	·01																
,, 6	·22																
,, 7	·03																
,, 8																	
,, 9	1·0												·0122	·176			
,, 10	..																
,, 11	·48																
,, 12	·02																
,, 13																	
,, 14																	
,, 15	·13																
,, 16	·66																
,, 17	·16																
,, 18	·20																
,, 19																	
,, 20	79																
,, 21																	
,, 22	·01																
,, 23	...																
,, 24	·55												·0343	·180	·0014	·68	·005
,, 25	1·22					...							·0343	·044	·0003	1·13	·009
,, 26	1·45							·1038	·140	·0033	13·73	·323					
,, 27	·35							·0199	·228	·0010	11·25	·051					
,, 28	·77	·1081	·038	0009	15·39	·375		7335	·078	·0130	4·95	·824					
,, 29	·04	·2268	·040	·0021	16·20	·834		·0197	·072	·0003	13·95	·062					
,, 30	..	·1305	·028	·0008	16·65	·493											
,, 31		·0462	·064	·0007	16·20	·170											

No Drainage.

STATEMENT NO. XIII (*c*).

Details of Drainage at Pusa, August 1910.

Date.	Rainfall, inches	GAUGE NO. I.					GAUGE NO. II.	GAUGE NO. III.					GAUGE NO. IV.				
		Drainage, inches.	Nitrogen in Drainage water.					Drainage, inches.	Nitrogen in Drainage water.				Drainage, inches.	Nitrogen in Drainage water.			
			As ammonia.		As nitrate.				As ammonia.		As nitrate.			As ammonia.		As nitrate.	
			Pts. per million.	Lbs. per acre.	Pts. per million.	Lbs. per acre.			Pts. per million.	Lbs. per acre.	Pts. per million.	Lbs. per acre.		Pts. per million.	Lbs. per acre.	Pts. per million.	Lbs. per acre.
Augt. 1	...																
,, 2	.																
,, 3	.																
,, 4	..																
,, 5	..																
,, 6	...																
,, 7	...																
,, 8	...																
,, 9	...																
,, 10	...																
,, 11	..																
,, 12	...																
,, 13	·11																
,, 14	·52																
,, 15	1·50							·0454	·018	·0014	29·70	·306	·0255	·130	·0008	1·13	·006
,, 16	·47																
,, 17	·64	·1733	·020	·0008	16·20	·637		·1020	·060	·0014	22·50	·521					
,, 18	·01	·2226	·038	·0019	16·20	·818		·0097	·475	·0010	27·00	·059					
,, 19	·88	·2012	·030	·0014	16·65	·760		·5072	·040	·0046	18·00	2·071					
,, 20	·10	·3124	...		16·65	1·180		·1345	·060	·0018	22·50	·687					
,, 21	·07	·1947	.	...	16·20	·716		·0496	·160	·0018	26·55	·299					
,, 22	.	·1091	·020	·0005	15·75	·390											
,, 23		·0385	·040	·0003	15·30	·134											
,, 24	·83	·0057	·020		13·90	·018		·2756	·008	·0005	3·37	·211					
,, 25	1·45	·1519	·008	·0003	14·85	·512		·2279	·034	·0018	26·10	1·350	·0082	·010		1·18	·003
,, 26		·4965	·022	·0025	14·40	1·622		·9483	022	·0047	27·90	6·003					
,, 27	...	·3873	·020	·0017	14·40	1·265		·0480	·610	·0066	38·20	·416					
,, 28	...	·1626	·020	·0007	11·70	·432											
,, 29		·0517	·020	·0002	11·70	·137											
,, 30	·28	·0081	·066	·0001	11·20	·021											
,, 31	·01	·0068	·034	·0001	9·90	·015											

No Drainage.

STATEMENT NO. XIII (*d*).

Details of Drainage at Pusa, September 1910.

Date.	Rainfall. inches.	GAUGE NO. I.					GAUGE NO. II.	GAUGE NO. III.					GAUGE NO. IV.				
		Drainage, inches.	Nitrogen in Drainage water.					Drainage, inches.	Nitrogen in Drainage water.				Drainage, inches.	Nitrogen in Drainage water.			
			As ammonia.		As nitrate.				As ammonia.		As nitrate.			As ammonia.		As nitrate.	
			Pts. per million.	Lbs. per acre.	Pts. per million.	Lbs. per acre			Pts. per million	Lbs. per acre	Pts. per million.	Lbs. per acre.		Pts. per million.	Lbs. per acre.	Pts. per million.	Lbs. per acre.
Septr. 1	·15	·0069	·020		9·00	·014	No Drainage.										
,, 2	·04	·0087	·034	·0001	9·00	·018											
,, 3	·19	·0219	·010		10·10	·050											
,, 4		·0220	·050	·0002	8·30	·042											
,, 5	·69	·0532	·010	·0001	11·70	·141		·2561			30·60	1·778					
,, 6	...	·1519	·032	·0011	11·70	·403		·0292	·250	·0016	36·90	·244					
,, 7	.	·0456	·030	0003	11·70	·121											
,, 8	·06	·0032	·220	·0001	10·80	008											
,, 9	·56																
,, 10	.	·0478	·030	·0003	10·35	·112											
,, 11	...	·0280	·014	·0001	9·90	·063											
,, 12																	
,, 13	..																
,, 14	..																
,, 15	·06																
,, 16	·01																
,, 17	1·18																
,, 18	·01	·0826			10·34	·194		·1953	·080	·0035	39·60	1·755					
,, 19	.	·1305			11·60	·343		·0043	1·480	·0014	48·60	·048					
,, 20		·0455			11·25	·116											
,, 21	·01	·0043	·132	·0001	10·80	·011											
,, 22	·57	·0262			10·80	·064		·1345			39·60	1·208					
,, 23	·02	·1305			11·25	·333		·0561	·200	·0025	40·50	·516					
,, 24	·02	·0695			11·25	·177											
,, 25		·0218			10·35	·051											
,, 26	·11																

STATEMENT NO. XIII (*e*).

Details of Drainage at Pusa, October 1910.

Date.	Rain-fall, inches	GAUGE NO. I.					GAUGE NO. II.	GAUGE NO. III.					GAUGE NO. IV.				
		Drain-age, inches.	Nitrogen in Drainage water.					Drain-age, inches.	Nitrogen in Drainage water.				Drain-age, inches.	Nitrogen in Drainage water.			
			As ammonia.		As nitrate.				As ammonia.		As nitrate.			As ammonia.		As nitrate.	
			Pts. per million.	Lbs. per acre.	Pts. per million.	Lbs. per acre.			Pts. per million.	Lbs. per acre.	Pts. per million.	Lbs. per acre.		Pts. per million.	Lbs. per acre.	Pts. per million.	Lbs. per acre.
Octr. 1	..	..	..	..	..	..	No Drainage.	..	..	..	..	..	..	..	..	..	..
„ 2	1·80	·0362	..	..	10·35	·085		·4058	..	..	39·60	3·646	..	..	..	..	..
„ 3	·12	·3745	..	..	10·80	·918		·4557	..	..	36·00	3·722	..	..	..	..	..
„ 4	·97	·2161	..	..	10·80	·530		·0553	·760	·0096	36·90	·463	·0054	·12	·0001	2·92	·004
„ 5	·70	·4772	..	..	10·80	1·169		1·0570	·100	·0239	32·40	7·770	·4229	..	..	·90	·086
„ 6	·08	·5906	..	..	10·80	1·447		·3580	·100	·0080	36·00	2·924	·2572	..	..	1·12	·065
„ 7	·02	·2803	..	..	10·12	·644		·0203	1·000	·0045	38·70	·178	·0548	·07	·0009	·67	·008
„ 8	·47	·1626	..	..	9·00	·332		·0648	..	..	28·80	·423	·1657	..	..	·45	·017
„ 9	..	·2140	..	..	9·00	·437		·1714	..	..	31·50	1·225	·1831	..	..	·45	·019
„ 10	..	·0984	..	..	9·22	·206		·0051	..	..	45·90	·053	·0120	..	..	·45	·001
„ 11	..	·0310	..	..	8·55	·060		..	..	..	..	..	..	..	..	..	..
„ 12	..	·0037	..	..	8·77	·007		..	..	..	..	..	..	..	..	..	..

STATEMENT NO. XIV.

Drainage at Pusa, 1910. *Totals for seven periods.*

Period.	Rainfall, inches.	GAUGE NO. I.			GAUGE NO. II.	GAUGE NO. III.			GAUGE NO. IV.		
		Drainage, inches.	Nitrogen.			Drainage, inches.	Nitrogen.		Drainage, inches.	Nitrogen.	
			As ammonia. Lbs. per acre.	As nitrate. Lbs. per acre.			As ammonia. Lbs. per acre.	As nitrate. Lbs. per acre.		As ammonia. Lbs. per acre.	As nitrate. Lbs. per acre.
June ..	7·46	..	..	..	No Drainage.	..	..	..	·142	·012	·054
July ..	9·34	·512	·004	1·793		·877	·017	1·237	·108	·003	·027
August 1-23 ..	4·33	1·252	·005	4·189		·848	·012	3·596	·025	·001	·010
August 24-30 ..	2·58	1·264	·006	3·543		1·500	·014	7·195	·008	..	·003
August 31 to Septr. 16	1·77	·396	·002	·912		·285	·002	1·842	..	..	..
September 16-30 ..	1·93	·511	..	1·199		·390	·007	3·444	..	..	..
October 1-12 ..	4·16	2·481	..	5·427	....	2·594	·046	19·300	1·102	..	·272
		6·416	·017	17·059	....	6·494	·098	36·614	1·385	·016	·366

STATEMENT NO. XV.

Details of crops grown on gauges at Pusa.

	Gauge No. II.							Gauge No. IV.					
	Air-dry weight.	N		P_2O_5		K_2O		Air-dry weight.	N		P_2O_5		K_2O	
		%	grms.	%	grms.	%	grms.		%	grms.	%	grms.	%	grms.
Maize, 1908.	grms.							grms.						
Grain	700	1·61	11·27	·61	4·27	·40	2·80	820	1·42	11·65	·53	4·35	·39	3·20
Cobs	420	·51	2·14	·13	·55	·72	3·02	430	·46	1·98	·10	·43	·91	3·91
Straw	1430	·61	8·74	·14	2·00	1·12	16·00	930	·71	6·60	·10	·93	1·31	12·20
Total dry-matter (lbs. per acre)	lbs. 5080	..	..	..	..	..	..	lbs. 4325	..	..	..	..	..	..
Estimated water transpired	inches 6·72	..	..	..	..	..	..	inches 5·72	..	..	..	..	..	..
Wheat, 1908-09.	grms.							grms,						
Grain	113·4	2·11	2·40	·87	·99	·51	·58	92·1	2·55	2·34	·78	·72	·42	·39
Straw, chaff, &c.	226·8	·51	1·16	·15	·34	1·54	3·50	170·1	·70	1·19	·17	·29	1·51	2·56
Total dry-matter (lbs. per acre)	lbs. 692	..	..	..	..	..	..	lbs. 525	..	..	..	..	..	..
Estimated water transpired	inches 2·59	..	..	..	..	..	..	inches 1·97	..	..	..	..	..	..
Maize, 1909.	grms.							grms.						
Grain	427·7	1·37	5·86	·62	2·66	·50	2·14	424	1·35	5·72	·67	2·84	·34	1·44
Cobs	195·2	·44	·86	·22	·43	·90	1·76	154	·53	·82	·26	·40	·90	1·39
Straw	1955·0	·55	10·80	·27	5·27	1·17	22·85	1522	·60	7·60	·28	4·25	·72	10·90
Total dry-matter (lbs. per acre)	lbs. 4150	..	..	..	..	..	..	lbs. 4130	..	..	..	..	..	..
Estimated water transpired	inches 5·48	..	..	..	..	..	..	inches 5·47	..	..	..	..	..	..
Wheat, 1909-10.	grms.							grms.						
Grain	993	1·89	18·75	·586	5·82	·638	6·33	736	2·52	18·57	·674	5·08	·664	4·89
Straw, chaff, &c.	2467	·71	9·02	·0601	1·44	1·155	28·49	2268	·34	9·16	·072	1·83	1·055	28·42
Total dry-matter (lbs. per acre)	lbs. 7312·5	..	..	..	..	..	..	lbs. 7093·7	..	..	..	..	..	..
Estimated water transpired	inches 11·29	..	..	..	..	..	..	inches 10·94	..	..	..	..	..	..
Maize, 1910.	grms.							grms.						
Grain	740·5	1·36	10·0	·57	4·21	·46	2·40	1116·2	1·30	14·50	·60	6·68	·48	5·35
Cobs	184·4	·29	·53	·13	·24	1·04	1·92	264·9	·44	1·16	·07	·18	1·01	2·67
Straw	1116·1	·48	5·34	·21	2·34	1·40	15·60	1259·9	·50	6·30	·14	1·76	1·37	17·20
Total dry-matter (lbs. per acre)	lbs. 4087	..	..	..	..	..	..	lbs. 5290	..	..	..	..	..	..
Estimated water transpired	inches 5·40	..	..	..	..	..	..	inches 6·99	..	..	..	..	..	..

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